Group model building as mutual persuasion

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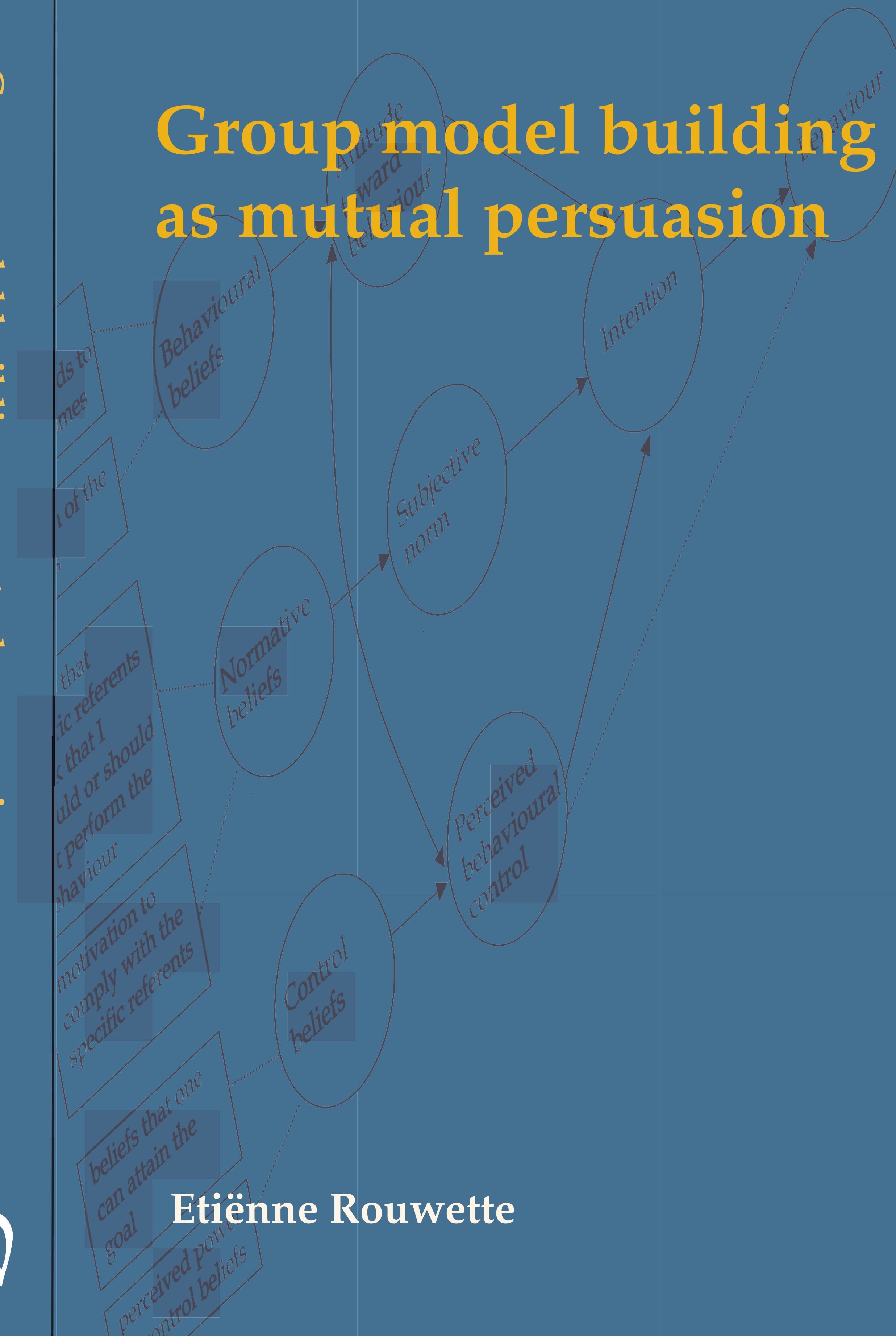


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# Group model building as mutual persuasion

E.A.J.A. Rouwette
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# Group model building as mutual persuasion

(Group model building als wederzijdse overreding)

een wetenschappelijke proeve op het gebied van
de Managementwetenschappen

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Etiënne Antonio Joseph Alfonso Rouwette
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Promotores: prof. dr. A.J.A. Felling
prof. dr. J.A.M. Vennix

Manuscriptcommissie: prof. dr. W.J. Scheper (Universiteit Utrecht)
prof. dr. D.F. Andersen (SUNY Albany)
dr. D.J. Vriens

# Content

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# Chapter 1 Introduction

## 1.1 Background of the study

The most difficult and influential decisions made in organisations are related to strategy. Decisions on organisational goals, new services or products, a merger or significant changes in human resources have wide impacts that are difficult to foresee. Effects will be felt throughout the whole organisation and long term consequences can be predicted in general terms at best. Researchers refer to these issues as strategic, messy or even wicked problems (e.g. Rosenhead, 1989), terms which underline the difficulty of getting a clear idea on the nature of these problems and their effects. Both researchers and managers perceive that organisations find themselves in ever faster changing environments, making more and more problems messy in nature. Deregulation, new technologies, and changing demand alter the environments of both profit organisations and government institutions. These developments introduce organisations to new issues and stakeholders, adding to the complexity of these problems. In order to cope with greater complexity, organisational decision making is changing as well. A decision maker is not able to oversee and handle messy problems on his own, let alone to motivate all stakeholders to pursue a shared strategy. Instead, decisions are more commonly made by teams of managers. Information is spread over various departments and individuals, and implementation of decisions will effect large parts of the organisation. In order to develop a feasible strategy, opinions of stakeholders will need to be considered and integrated.

However, exchanging ideas on a complex and urgent issue, in a group of stakeholders that each have their own particular view and interests, is a problem in itself. Differences of opinions and interests are almost a guarantee for long and frustrating discussions. Tensions may run so high that an outcome acceptable to all participants cannot be reached. Frequently the inability to oversee a complex issue leads the organisation to adopt a strategy of 'muddling through' (Lindblom, 1959). Large changes are avoided in order to prevent unforeseen consequences. In many cases this strategy may fail to get to the heart of the problem. The literature on messy problems offers examples of situations in which opposing parties prevent any decision from being taken, leading to a standstill that threatens the organisation's survival (e.g. Hall, 1984). In the worst case, ineffective decisions may result that have disastrous consequences (Hall, 1980). At best these meetings are inefficient and fail to realise their full potential. Meetings in which each participant is convinced she is right, run the risk that arguing for one's own position prevents a constructive discussion. Ideally, strategic decisions would be based on a common view in which all pieces of information are brought into the open and integrated (De Geus, 1988). Creation of a shared view presupposes that team members are able to learn from each other. Instead of soliciting arguments to back up their own view, this involves trying to understand others' ideas, estimating consequences for already formed opinions, and integrating new and old information.

Since combining diverse opinions is the basis for effective strategic decision making, but fraught with difficulties, it comes as no surprise that there is an abundant literature on guidelines and approaches to support meetings. These approaches are commonly known as group decision support systems (GDSS). A GDSS offers a systematic way to exchange and integrate diverse viewpoints. GDSS are different from common meetings led by a chairperson in a number of ways. Common to all GDSS is that the person leading the process is neutral with regard to content. This person acts as a facilitator: he or she makes sure that all participants have an equal chance to air their ideas and that a shared view of the problem is constructed. The facilitator therefore focuses on process and does not make suggestions with regard to the content of the discussion. This is different from a chairperson, who frequently has a stake in the issue at hand and is not perceived as neutral. Some GDSS support the exchange and integration of ideas by building a simplified representation of the problem, or put more simply, by constructing a model. The model is presented in front of the group and visible to all participants. Instead of a verbal discussion and written minutes that become available only after the meeting, ideas are translated into model elements and immediately added to the existing model. In this way, the content covered in the discussion is always available for direct inspection and continuously updated with new ideas. Analysis of the model is expected to result in feasible actions that will alleviate the problem. The use of model experiments increases the insight into the effects of interventions in the problem, while avoiding the potential disastrous consequences of experimenting with reality (Sterman, 1994). Several GDSS use computer hardware en software to enable participants to contribute ideas or to build a model, while others only use flipovers, paper and pencils. All GDSS share the idea that traditional meetings fall short of realising the full potential of combining individual ideas. In comparison to traditional meetings, changes with regard to the process, orientation of the process leader and the way of keeping track of the discussion are needed to enable participants to learn optimally.

What may be clear from the description so far, is that goals of meeting support are rather ambitious. GDSS aim at enabling participants to learn, create a common view on the problem and work towards an outcome acceptable to all participants. GDSS assume that participants are willing to reach a joint decision. The literature on GDSS abounds with concepts such as insight, team learning, consensus, shared view,

commitment and quality of communication. In addition, a variety of ways to bring about these goals are proposed. Facilitation, structuring of the process and construction of a model are expected to contribute to these aims. This study is concerned with the question to what extent a particular GDSS is successful in accomplishing these goals. In answering this question, two perspectives turned out to offer useful and complementary insights. The first perspective is theoretical, while the second is empirical. Issues that are central with regard to the theoretical perspective are the following: how are decisions made in organisations in practice? What would optimal decision making look like? How are GDSS used to support decision making, i.e. what assumptions are made, what does the application of a GDSS to a specific problem look like, what are the expected outcomes of such an intervention in an organisation? A discussion of these issues reveals that GDSS can take various forms and the application of any GDSS will always be adapted to the problem and organisation at hand. Evaluation of the success of a GDSS is therefore not a straightforward matter. The first step in bringing the number of goals and intervention elements that need to be considered down to manageable proportions, is the selection of a specific GDSS as the focus for further research. Group model building is chosen for a number of reasons. The method is the only GDSS to approach complex problems with a combination of facilitation and quantitative dynamic modelling. This has led to an accumulation of research results which can be used as a basis for the empirical part of this study. Furthermore, the researcher's direct experience with group model building makes it more likely that practical considerations and implicit assumptions which are not well described in the literature, are taken into consideration as well.
The second perspective has an empirical character. As a result of the theoretical exploration, several gaps in the conceptualisation of GDSS goals and process are discovered. How a GDSS exactly contributes to the creation of a shared view is not discussed in detail in the literature. GDSS goals such as increasing insight into the problem and creation of consensus are not clearly defined. And although goals are clearly related, the influence of e.g. insight and consensus on commitment is not clear. In the second part of this study, conceptual models from social psychology are borrowed to define central concepts, to define relations and to operationalise process and goal variables. This framework is tested in a study of five organisations that applied group model building to a messy problem.

## 1.2 Purpose and audience

This research serves several purposes, which are closely related to the theoretical and empirical perspective on decision support described above. The five basic questions this study aims to answer are the following:

1. What are the intended effects of group model building on decision making?
2. How do the practical steps in group model building contribute to these goals?
3. How can the effects of group model building be researched, i.e. how can relevant variables be operationalised and measured in both a scientifically sound and practical manner?
4. To which extent does group model building accomplish its goals?
5. How can group model building be adapted to achieve its goals more efficiently and effectively?

This study is intended for two audiences: academics and practitioners in the field of modelling. The first audience will primarily be interested in the contribution of this study to theory, operationalisation, and empirical research. Practitioners in system dynamics and other fields of modelling will most likely be interested in the last question, provided they feel that the process of modelling can still be improved. One of the starting points of this research is that modelling is more often an art than a science. If this is true, modellers must frequently work from implicit and/ or untested hunches and insights. My interest in working on this topic was to try and bring together these scattered insights, find a general framework to relate what modelling does to clients and how, and use this framework to test a set of interventions. This has the double benefit of making modelling a more transparent and testable process, which in turn makes it easier for novices to learn what modelling is about and for clients to see what they have gained from the effort. I hope, therefore, that modellers who are interested in testing their assumptions find something of their benefit here. Practitioners may want to skip to section 8.4, which summarises the results with regard to future modelling interventions, and use this to identify other sections of the text which might be of interest.

## 1.3 Preview of the study

As outlined above, this study will describe the impact of GDSS from two perspectives. The first perspective is theoretical and starts with a general description of decision making. This will be the topic of the *second chapter*. This chapter primarily aims to introduce the background of decision making support. The reader already familiar with this topic may want to pass over the description of the decision making literature and the goal of decision support, and proceed directly to the conclusions in section 2.6. The decision making literature will be discussed from a descriptive and a prescriptive viewpoint, on three levels: individual, group and organisational. Descriptive studies focus on actual decision making practices, while prescriptive studies offer either normative orientations or more practical guidelines for supporting decision making. In the latter category, descriptions of several GDSS can be found. The remainder of chapter will address a couple of questions. The first is: what is group model building? This will be addressed by describing the assumptions underlying the approach, its two basic components (modelling and facilitation) and the different forms of group model building which can be found in the literature. After describing what the intervention looks like, a second question is in which situation it is applied: when is group model building used? This leads to a description of complex organisational problems and the further question of what modellers aim to accomplish in these situations. The answer to this last question, why group model building is used, calls for a definition of modelling elements, goals and their relationships. This concludes the discussion of the descriptive literature on group model building.

*Chapter three* continues the discussion by reviewing the empirical literature on the application of group model building. Before new empirical research is started, it is useful to take stock of the results of previous studies on effectiveness of modelling. Studies on the use of modelling in complex problems are scanned and compared. The goal of this chapter is to identify robust outcomes of modelling, on which the empirical part of the study can be based. Several questions are addressed. Which outcomes of modelling projects can be found consistently across different types of organisations and problems? Does the specific approach to modelling, e.g. whether a qualitative or quantitative model is constructed or the size of the model, have an impact on these outcomes? The conclusions of this chapter point to specific combinations of context (organisational and problem characteristics), mechanism (the modelling intervention) and outcome (goals of modelling).

In *chapter four* theories from social psychology are used to form a preliminary conceptual model of group model building effectiveness. For central goals of group modelling, such as commitment and consensus, a clear equivalent can be found in social psychology. The theory of planned behaviour (Ajzen, 1991) is used to describe the relations amongst goals of modelling. This theory focuses on the influence of beliefs and evaluations on actions. Theories on persuasion (Chaiken, Lieberman and Eagly, 1989; Petty and Cacioppo, 1986) are used to describe how modelling influences participants, particularly with regard to beliefs (insight) and evaluations. Persuasion theories describe how beliefs and evaluations change as a result of information and other clues contained in a message.

The switch to the empirical perspective on group model building effectiveness is made in *chapter five*. In this chapter, the theories from the previous chapter are used to define research hypotheses. In the hypotheses, the expected influence of the intervention on mechanism and outcome variables is detailed: group model building is expected to change cognitions, evaluations and actions, and lead to an exchange of persuasive messages. Criteria for choosing a research design are discussed and the one group pretest posttest design is chosen. Threats to the validity of the approach are identified. Variables are operationalised and scales are constructed, mainly based on the theories discussed in chapter four.

*Chapter six* provides a short description of the context, mechanism and outcome for each of the five cases in the study. The organisation and the problem addressed in the modelling sessions are outlined. For each case the way in which group model building is used to identify and integrate participants' ideas is listed. This boils down to a description of the persons involved in group model building (participants and facilitators), duration of the intervention, the techniques used for modelling and the final model constructed. The outcome of each modelling project is described with regard to dissemination of results and system changes.

*Chapter seven* focuses on the results of the empirical part. The chapter starts with a description of context, mechanism and outcome separately. With regard to context two questions are addressed: are the expected context variables present in the five cases? Are context factors related to each other? The same questions are addressed with regard to mechanism and outcome variables. In the second section relations of one category to another are described, i.e. how do context and mechanism combine to influence outcomes of modelling? This answers the hypotheses on the impact of modelling on outcomes: if persuasive messages are exchanged, are these related to the change in cognitions and evaluations? Finally, the five modelling cases are checked to see if the context-mechanism-outcome patterns that were found in chapter three can be found in the data.

*Chapter eight* reports the conclusions of this study and discusses results. First, the value of the conceptual model described in chapter four is addressed, with regard to the theory of planned behaviour as well as the persuasion theories. Next, benefits and limitations of the measurement method are identified. The results of the empirical part of this study, as well as the observations on the conceptual model, provides reasons to rethink several aspects of the intervention. Finally, implications for further research are outlined.

# Glossary

Argument: '… bits of information contained in a communication that are relevant to a person's subjective determination of the true merits of an advocated position' (Petty and Cacioppo, 1986: 133).

Attitude: 'a psychological tendency that is expressed by evaluating a particular entity with some degree of favor or disfavor' (Eagly and Chaiken, 1993: 1).

Attitude toward behaviour: 'a person's general feeling of favorableness or unfavorableness' [toward the behaviour in question] (Ajzen and Fishbein, 1980: 54).

Commitment: 'an agreement or pledge to do something in the future, the state of being obligated or emotionally impelled' (Webster's dictionary).

Complex problem: a discrepancy between an actual and a desired state which is high in either social or analytical complexity, or both (see also messy problem).

Context: conjunction of organisational and individual variables that, in combination with mechanism variables determines the outcome of an intervention in a social system.

Evaluation: attitude, subjective norm and perceived behavioural control.

Facilitation team: persons supporting the participants in system dynamics modelling sessions, consisting of the roles of facilitator, process coach, recorder, modeller and gatekeeper.

GDSS: Group decision support system, '… a set of software components, hardware components, language components, and procedures that support a group of people engaged in decision-related meetings' (Huber, 1984: 197).

Group model building: a group decision support system that combines system dynamics modelling and group facilitation.

Intention: 'Intentions are assumed to capture the motivational factors that influence a behaviour; they are indications of how hard people are willing to try, of how much of an effort they are planning to exert, in order to perform the behaviour' (Ajzen, 1991: 181).

Mechanism: the total of characteristics of an intervention in a social system that, in combination with context variables, determine the outcome of the intervention.

Messy problem: the discrepancy between an actual and a desired state, which is high in both social and analytical complexity.

NGT: Nominal Group Technique, a procedure aimed at supporting group decision making described by Delbecq, Van de Ven and Gustafson (1975), consisting of the following steps. a. participants write down ideas in silence; b. ideas are collected in a round-robin fashion and recorded on a flip chart or whiteboard; c. each idea is discussed for clarification and evaluation; d. ideas are voted on individually and prioritised.

Outcome: consequences of a behaviour.

Perceived behavioural control: ‘perception of the ease or difficulty of performing the behavior of interest’ (Ajzen, 1991: 183).

SAST: Strategic Assumptions Surfacing and Testing, a group decision support system developed by Mason and Mitroff (1981).

SODA: Strategic Options Development and Analysis, a group decision support system developed by Eden (1989).

SSM: Soft Systems Methodology, a group decision support system developed by Checkland (1981).

Subjective norm: ‘perception that most people who are important to him think he should or should not perform the behavior in question’ Ajzen and Fishbein, 1980: 57).

# Chapter 2 The intervention

## 2.1 Introduction

This chapter introduces the intervention method that is the central topic of this research. The intervention is part of a wider family of methods used to support decision making in complex, strategic problems in organisations. As mentioned in the introduction, this chapter aims to familiarise the reader with the background of decision support. Readers familiar with this literature may want to read the conclusions in section 2.6 and use these to identify relevant sections in the remainder of the chapter. The following provides an overview of the topics discussed in each section.

Section 2.2 discusses the literature on decision making, from a descriptive as well as a prescriptive viewpoint. Both viewpoints address decisions made at the individual, group and organisational level. The descriptive literature focuses on decision making practice and identifies a large number of deficiencies of traditional, unsupported decision making. The prescriptive tradition offers a number of methods and techniques aimed at overcoming these limitations.
Section 2.3 describes the two major building blocks of group model building: system dynamics modelling and group facilitation. A practical example will be given of how managers construct a model in a series of meetings. The example serves to introduce the general 'toolkit' a model builder might choose from, while working with a group. The general approach is then further detailed by describing six approaches to group model building that each make specific choices with regard to modelling techniques and tools.
In section 2.4, the type of problems to which group model building is applied will be addressed in more detail. In these complex problems both the process of decision making as well as the topic of the decision present difficulties to the managers involved. An incremental approach, that helps in framing relevant questions and gradually increases managers' insight into the problem is necessary to overcome these difficulties.
Section 2.5 describes the specific contributions group model building can make to decision making in complex problems, i.e. the goals of the intervention. Examples of intervention goals are improvement of the quality of communication between members of a management team and creation of a consensus view of the problem.
In section 2.6, the main elements and expected outcomes of group model building are summarised. Two major conclusions for future research into effectiveness of group model building stand out. The first is that new empirical research needs to build on the results of previous studies. Results that are consistently found can help in

framing relevant research questions. Hence in the third chapter the results of previous studies will be explored. The second conclusion is that the prescriptive literature considered so far, discusses elements and outcomes of group model building largely in isolation. A number of hints on how a particular element of the method contributes to goals can be found in the literature, but an overall framework relating major elements of the method to expected outcomes is missing. An attempt at formulating a more general framework to explain relations between group model building elements and outcomes will be made in chapter four. This framework will then be used in the empirical part of this thesis, for which hypotheses will be formulated and a design chosen in chapter five.

## 2.2 Decision making from a descriptive and prescriptive viewpoint

### 2.2.1 Introduction

In this section the background of this study is sketched, by giving a general overview of the literature on decision making on the individual level, in groups, and in organisations. An organisation can be seen as a formal hierarchy of positions, created to achieve coordinated action (Simon, 1957; Scheper, 1991). A major reason for the existence of organisations is that in contrast to individuals, they are better able to deal with complex problems that make coordination of a number of actions necessary. Consider for example a single individual charged with overseeing and managing the complete process from conceptualising a new software tool, designing and testing a prototype, to marketing and manufacturing of the finished product. Although in principle it is possible for an individual to handle all of these processes, if a product grows more complicated or processes become more interdependent it will be become less and less likely that decisions are made in a timely manner. In general decisions on what to do in each of these phases, how to do it and implementation are distributed over multiple individuals and some form of coordination is required. Problems an organisation is repeatedly faced with, will give rise to a more or less standardised reaction (Simon, 1957). A marketing firm specialised in software products will have developed a series of routines for deciding how to market new software. A production firm will know how to deal with a large number of manufacturing problems routinely. However, organisations will at times be faced with strategic decisions that are new, important to the organisation as a whole and have long-term impacts. For these problems usually no decision making routines have been developed, since a situation that is completely similar has not been encountered before (Rittel and Webber, 1973; Mason and Mitroff, 1981). Examples are a firm faced with the decision where to locate new plants, or a public agency deciding whether or not to merge previously independent services. Since the effects of these problems surpass the boundaries of a single department, routine decision making procedures are not sufficient in these situations. One reaction to this type of problems is to set aside the traditional hierarchy of decision making responsibilities for an alternative procedure in which a team of managers jointly tries to reach a decision. This means that both the content and process of the decision are novel and unique to the managers involved.

Above, routine decisions are contrasted with more strategic and complex decisions. In the decision making literature, many more distinctions and typologies of decisions and decision making processes can be found. An important distinction can be made between a descriptive and a prescriptive orientation. The descriptive literature offers empirical studies and theoretical models of decision making practice. In the prescriptive tradition methods and procedures are presented to overcome major shortcomings in decision making at the individual, group as well as organisational level. This literature does not focus on how decision making procedures *are* carried out in practice, but rather on how they *should* be carried out. In order to provide a background for the literature used in this study, descriptive and prescriptive studies into decision making are addressed shortly in the following subsection.

### 2.2.2 Descriptive studies

The literature on decision making offers descriptions from an individual, group and organisational perspective. These perspectives are discussed in turn.

*Individual*

In the field of individual decision making, Tversky and Kahnemann's studies on individual judgment tasks are well known. In a series of laboratory experiments (e.g. Tversky and Kahnemann 1974; 1981) a number of biases in human decision making were identified. One of these biases occurs when people try to judge the likelihood of an event. In general people will not consider prior probabilities when trying to assess probabilities. People will for example estimate that after 12 times red at a roulette table, black will have a much higher chance of occurring while in fact its probability will still be 50 percent. Several biases are introduced by the social context of the decision maker. The experiments by e.g. Asch (1963) show how the opinion of other participants can influence a subject in a simple judgmental task. In estimating which of three lines is equal in length to a projected standard, a large proportion of people tends to follow the majority's opinion even though this does not match their own opinion. Other studies have identified many additional biases and heuristics (see e.g. Hogarth, 1987; Vriens, 1998). Apart from biased processing of information, human decision making is also limited by the fact that it uses only a subset of the available information (Simon, 1985; Miller, 1956). This biased as well as limited use of available information ensures that humans are poor decision makers in complex environments, and do not improve their performance much, even after being given ample opportunity for learning (Sterman, 1994; 2000).

*Group*

Group decision making is studied in social psychology. The conceptual models in this field are frequently classifications of variables that in some way impact decisions in groups (Scheper, 1991). Many of these are based on McGrath's (1984) model, that classifies both the variables important to decision making as well as decision making tasks. McGrath organises the most important variables in group decision making in three classes:

- input: characteristics of the situation, group, type of task and task support;
- process: type of decision (e.g. vote or consensus), characteristics of communication, interpersonal relations and structure of the process;
- output: task-related outcomes (e.g. quality of decision, consensus) and group-related outcomes.

An important element of decision making input is the task with which the group is confronted. McGrath distinguishes between four types of group tasks: generation, choice, negotiation and task execution. Two types of choice tasks are distinguished: intellective and decision making tasks. In an intellective task the choice is to identify the correct answer. In a decision making task there is no single correct answer and the group has to decide on a preferred solution. In McGrath's model, group task and other input characteristics operate in combination with process variables to determine the outputs of the decision making process. Later additions to the model (e.g. McGrath and Hollingshead, 1994) expand McGrath's formulation by taking into account different decision making functions, modes and activities.

Common to all of these models is the fact that they address relations between classes of variables instead of relations between specific variables. Since they do not relate specific variables, these models can be said to lack explanatory value (Scheper, 1991). However, McGrath's and similar models have inspired a large number of empirical studies in laboratory settings (e.g. Pinsonneault and Kramer, 1990; McGrath and Hollingshead, 1994). After reviewing this research, McGrath and Hollingshead conclude that empirical results are frequently conflicting and it is difficult to find general patterns. In order to compare findings, a conceptual framework would be needed that encompasses all potentially relevant factors in group decision making. Their review for example shows that unsupported, face-to-face decision making groups produce higher quality outcomes than computer supported groups on certain tasks, but not on others. In intellective and negotiation tasks unsupported groups tend to outperform computer supported groups, but the latter are more effective in

idea-generation. This means that type of support and task type interact to produce outcomes of decision making. The majority of the research in this field is conducted with ad hoc groups that are brought together for a single session. The generalisability of results to groups with a longer history or more experience is not clear (McGrath and Hollingshead, 1994: 92).
Apart from comparisons of unsupported and supported groups, other studies in social psychology describe many phenomena that play a role in group decision making. Examples are defensive routines (Argyris, 1990), minority and majority influences (Eagly and Chaiken, 1993), groupthink (Janis, 1972) and communication in decision making tasks (Orasanu and Salas, 1993). Although in this field a number of naturalistic studies can be found, most research is done in laboratory settings. In conclusion the large number of variables and the wide diversity of topics studied in relation to group decision making, have two important consequences: conceptual models are formulated at a general level and research is only beginning to address the interaction of variables involved in group decision making. Both factors make it difficult to select a conceptual model for this study from the literature.

*Organisation*

Finally, studies of decision making in organisations are in some respects similar to the models of individual decision making that were addressed at the beginning of this section. Both fields of decision making highlight how only a subset of the available information is used. The most influential description of organisational decision making is probably Simon's (1957) model of bounded rationality (Pool, 1990). According to this model, a decision maker in an organisation will not have all the information on probabilities and outcomes of decisions. Instead his knowledge will be limited or bounded. He will therefore not succeed in choosing the optimal alternative that maximises outcomes, but arrives at a decision that is good enough. This way of decision making is referred to as satisficing instead of optimising behaviour. Other classical studies show how organisational routines and departmental subgoals function as boundaries on rational decision making (March and Simon, 1958). Lindblom (1959) elaborates on the hierarchical relation between organisational goals. Decisions are most often made on the basis of low-level or local goals, without considering the overarching goals of the organisation. This leads to incremental decision making or 'muddling through': taking small steps that do not change the current situation too much, and adjusting actions on the basis of feedback. Cyert and March (1963) and Pettigrew (1973) draw attention to the fact that an organisation is not a unitary entity with a single set of goals, but consists of separate groups that might have conflicting goals. A line of empirical studies (Witte, 1972; Mintzberg et al., 1976; Nutt, 1984; Hickson et al., 1986) shows how organisations navigate between decisions that satisfy overarching organisational goals and accommodation of the interests of all groups involved. Hickson et al. (1986: 249) find three different rationalities underlying organisational decision making: an interest-accommodating rationality that ensures that the goals of all relevant groups are considered, a problem-solving rationality that tries to arrive at the best possible solution, and a rationality of control that guides the coordination of activities in the organisation. The authors underline that the simultaneous operation of these three rationalities does not need to be rational. Conflicting interests might prevent the best solution to be chosen. In the example of the software product, the design department might favour a complex product which raises difficulties for manufacturing and marketing. Deciding which solution is best to the organisation would, among others, involve determining costs of development, production and expected sales of alternative products. The software product that scores best on these goals is not necessarily acceptable to all departments. Decision making then boils down to balancing organisational goals and lower level goals of subgroups.

### 2.2.3 Prescriptive studies

The descriptive studies in the foregoing section address characteristics and elements of actual decision making practice. In the theories that are the topic of this section, the objective is to identify a standard of optimal or ideal decision making. A description of decision making in its optimal form, without reference to its practical implications, is a normative theory of decision making. If a theory is used to improve decision making in a practical sense, it is used prescriptively (Schoemaker, 1982: 541).

*Individual*

At the individual level, the ideal is a rational decision that optimises expected gains. The subjective expected utility model by Tversky and Kahnemann (1981) is one of the candidates for this standard (Schoemaker, 1982). In this model it is assumed that the probability and subjective value of all outcomes of a decision alternative can be assessed. The value of an alternative is then estimated by multiplying probabilities and values per outcome, summarising for all outcomes. Following the model, the alternative with the highest value will be chosen. As described in the previous section, Simon (1957) and other authors feel the subjective utility model has limited value for *describing* actual decisions. The model however still functions as a baseline for rational decisions.

*Group*

At the group level, a number of normative theories can be found, as well as prescriptive models that offer practical procedures for group decision making. An example of a theory that is in part normative is Daft and Lengel's (1986) work on media richness. Daft and Lengel propose that media differ in the richness of information they provide. A participant in a discussion uses both verbal and nonverbal information when inferring the meaning of a message, while a reader of a text can only use verbal clues. On the other hand, situations differ in the amount of information needed. In negotiation not only the content of spoken communication is taken into account, but also intonation, facial expressions and the like. In this situation all of this information is needed to interpret the position of the other party, while e.g. in a brainstorm the content of written or spoken text would provide sufficient information. Daft and Lengel therefore conclude that a communication medium needs to be selected on the basis of the type of situation it will be applied in.

In a related field of the literature, normative guidelines are supplemented with practical procedures for more effective group decision making. An early example is Delbecq et al. (1975) Nominal Group Technique (NGT). The authors describe a set of features of effective group decision making. These include elements such as obtaining agreement on the general approach to the decision (the agenda), involving clients to identify needs and involving managers that will be responsible for implementing decisions. NGT is then presented as a practical procedure that meets these criteria. The procedure is laid out in a series of steps that are expected to enable maximum involvement of participants in a group meeting. The steps in NGT boil down to the following:

- participants write down ideas in silence;
- ideas are collected in a round-robin fashion and recorded on a flip chart or whiteboard;
- each idea is discussed for clarification and evaluation;
- ideas are voted on individually and prioritised.

NGT is thus meant as an alternative to traditional face-to-face meetings that lives up to certain selected criteria for effective decision making.

Procedures that aim to enhance effectiveness of group decision making are generally referred to as group decision support systems (GDSS). In addition to a specific procedure such as offered by NGT, some GDSS employ computers for supporting group decision making. Huber's (1984: 197) definition of GDSS refers to both the procedure as well as the physical infrastructure used for support. He defines a GDSS as: '… a set of software components, hardware components, language components, and procedures that support a group of people engaged in decision-related meetings.' A typical example of a computer-supported GDSS is GroupSystems developed at the University of Arizona. If GroupSystems is used to support a face-to-face meeting, participants will gather in a so-called group decision room. This room contains a series of networked computers arranged in a U-shape. Every participant is seated behind a computer and faces a projection screen. The GroupSystems software allows for sending out questions to the individual computers, collection of answers that can be projected on the central and individual screens, and various ways of categorising and prioritising ideas. Participants contribute to the meeting largely by typing in responses to questions on their computer screen. GroupSystems and related approaches have been in use since the late 1970s and their impact has been researched in the descriptive literature mentioned earlier (e.g. McGrath and Hollingshead, 1994). Because most GDSS of this type originated in the US, the approaches are also known as US GDSS.

In other GDSS computers play a far less important role. These GDSS are known as 'wide-band' GDSS (Eden, 1992a) as they take into account aspects of decision making that go beyond a single meeting. Where GroupSystems mainly supports information exchange during a meeting, wide-band GDSS aim to structure and integrate information and aid in the negotiation process between meeting participants. Their ultimate goal is to help a group reach a decision and create commitment to actions (Eden, 1992a). Wide-band GDSS have a background in operational research (Rosenhead, 1989). Traditionally, the approach works by constructing a model of the decision problem (Checkland, 1981: 73). An example of a wide-band GDSS is Eden's (1989) Strategic Options Development and Analysis (SODA). The first step in applying SODA is to identify managers that need to be involved in the decision process. Secondly, these managers are interviewed individually and their ideas on the decision problem recorded in a so-called cognitive map. The map consists of actions and goals that are connected through arrows, denoting influence of one on the other. An example of the software product process might illustrate this. The mental map of a designer might contain an influence of 'functionality of product' on 'adaptability to user demands'. A manager of the marketing department might however link 'functionality of product' to 'product complexity'. In the third step of SODA, individual maps are combined into a 'strategic map' for the group as a whole. In the example the map would show both consequences of product functionality. The map will then be used to structure a discussion and negotiation on the relative value of each consequence. The expected outcome of a SODA process would be consensus on the consequences of changes in product functionality, and commitment to a course of action. In this way the model serves both as an integrated view of the problem as well as a negotiation device. In SODA and other wide-band GDSS the model is thus no longer seen as a description of reality as in traditional operational research, but more as a coherent combination of problem perceptions. Since wide-band GDSS do not share many of the assumptions of traditional 'hard' operational research, they are alternatively known as soft operational research methods or problem structuring methods.

*Organisation*

A number of normative models of organisational decision making can be found in the literature. An example is Drucker's (1988) knowledge based organisation. Drucker proposes that organisations faced with complex problems should be organised on the basis of shared goals. This will enable local decision making and a faster reaction to changes in the environment. The assumption that decision making responsibility is shared by a team of managers can be found in many GDSS as well (Scheper, 1991). A second example is Huber's (1990) idea on the impact of new technology in organisations. He assumes that if information technology becomes available to an organisation, managers will start to use it and thereby increase information accessibility. Ultimately, the introduction of information technology will make organisational decision making more effective. Similar to theories on individual decision making, these models are largely normative and procedures for attaining the norm are largely lacking. An exception is the literature on organisational learning (e.g. March and Simon, 1958; Senge, 1990; Argyris, 1992) that offers some guidelines for increasing the effectiveness of decision making at the organisational level. Senge (1990) describes e.g. a procedure for fostering shared goals.

### 2.2.4 Summary of descriptive and prescriptive studies

In sum, the literature used in this study can be separated into a descriptive and prescriptive orientation. Decision making is influenced by elements at the individual, group as well as the organisational level. The following table draws the most important contributions to this literature together.

| | *Individual* | *Group* | *Organisation* |
|---|---|---|---|
| *Descriptive* | Conceptual models e.g. Vriens (1998)<br>Selection mechanisms e.g. Tversky and Kahnemann (1974), Hogarth (1987) | Input- process- output models e.g. McGrath (1984)<br>Laboratory studies e.g. McGrath and Hollingshead (1994)<br>Naturalistic studies e.g. Orasanu and Salas (1993) | Conceptual models e.g. Simon (1957)<br>Empirical studies e.g. Hickson et al. (1986), Mintzberg et al. (1976) |
| *Prescriptive* | Rational actor models, e.g. subjective expected utility (Tversky and Kahnemann, 1981) | Normative models e.g. media richness (Daft and Lengel, 1986)<br>Methods e.g. NGT (Delbecq et al., 1975)<br>Prescriptive e.g. GDSS (McGrath and Hollingshead, 1994)<br>Soft OR (Rosenhead, 1989) | Normative models e.g. knowledge based organisation (Drucker, 1988), new technology (Huber, 1990)<br>Prescriptive e.g. learning organisation (Argyris, 1992) |

*Table 2.1 Framework and examples of decision making studies*

Neither at the individual, group nor organisational level does a comprehensive model of decision making, which combines all the elements relevant to a level, exist. However, a common finding is that only a limited amount of information is used in arriving at a decision. At the individual level many selection mechanisms operate to prevent a scan of all available information. Traditional face-to-face meetings also fall short of the ideal of gathering and combining all data. Studies on decision making in organisations underline the complexity of determining which goals are to be considered in arriving at a decision. The literature on group decision making does present some guidelines for increasing effectiveness of group decisions, some of which are applied in the methods and techniques described in the previous section. As stated, in this study one of these methods will be selected and its effect on the process and outcome of group decision making researched. The descriptive and prescriptive studies described above serve as a foundation for this research. Previous studies into the effects of wide-band or soft operational research methods offer concepts and methodological guidelines, while the various descriptive models will be considered when trying to determine which elements need to be included in the evaluation of a method.

The discussion of the descriptive literature makes it clear that there is a large number of variables involved in decision making. Decision making support can take many forms and focus on a wide variety of goals. The literature offers several suggestions on the effect of interventions, but no integrated conceptual model relating intervention elements to goals. Without a more specific idea on the intervention to be studied, it is impossible to determine which theories and empirical studies are relevant for the empirical part of this study. It seems therefore useful to first describe the characteristics of the intervention and the situation it is applied to, before choosing which part of the literature to focus on. The intervention process and the type of decisions which it aims to support are addressed in the following two sections. Section 2.3 describes the intervention that is the subject of this research: group model building. Section 2.4 goes into the situation in which group model building is applied: complex strategic problems.

## 2.3 Group model building

In the previous section a number of methods for supporting group decision making were described. In this section one particular method is chosen as the central topic for the remainder of this study. After describing the arguments for this choice, a practical example of the use of group model building for decision making support is described. In group model building insights from two fields are used: system dynamics and group facilitation. The system dynamics approach is described by outlining its fundamental assumptions and the different phases of model construction. Next a short description of facilitation is given.

### 2.3.1 Selection and introduction

There are a number of reasons to select group model building from the different GDSS described in the previous section. First, the method has been used in messy problems with potentially serious consequences to an organisation (e.g. Hall, 1984). As one of the wide-band GDSS, the aims of group model building go beyond supporting the exchange of information in a meeting. With its focus on consensus and commitment to decisions, the approach aims to create shared action in strategic organisational problems.

Second, the method offers a well-described combination of modelling and facilitation. Vennix (1990: 37) provides the following argument for choosing participative system dynamics modelling over other approaches as the topic for his research:

> *'We will, however, not try to evaluate the suitability of each of these modelling methods for a participative approach. This would demand a thorough knowledge of and experience with these methods, which we do not possess. Rather, we will take as our point of departure one of these methods, i.e. the system dynamics approach, since*

*modellers from this school have not only repeatedly emphasized the need for client involvement in modelling but have also frequently realized participative modelling .'*

This statement has gained in importance since in recent years the facilitation aspect of system dynamics has been more firmly grounded in theory and practice (Vennix et al., 1992; Vennix, 1996; Andersen and Richardson, 1997). Facilitation aims at involving stakeholders directly in the decision making process. Involvement of stakeholders is important both for structuring a problem as well as ensuring implementation of conclusions (e.g. Schein, 1987). Although other soft operational research methods have also evolved further with regard to their base in participative methods (see e.g. Eden and Radford, 1990; Checkland and Scholes, 1990) their translation of group decision theory and practical experience into methodological guidelines is less explicit.

Apart from its focus on important organisational problems and facilitation background, a third argument for the choice of system dynamics is its use of quantitative modelling. Lane (1994) describes how system dynamics, by setting itself apart from mainstream operational research, has avoided many of the criticisms levelled at hard operational research. This has led to a continued use of quantitative modelling including an attempt to involve clients in formalisation and quantification phases, while other wide-band GDSS rely almost exclusively on qualitative techniques. Quantitative modelling is often considered crucial to the understanding of dynamic behaviour of problems (this is addressed in more detail in section 2.3.3). Even if system dynamics is used in a purely qualitative manner, it will be informed by insights into the connection of problem structure and problematic behaviour gained from quantified models.

Fourth, over the years system dynamics has seen an accumulation of research in the form of case reports and field experiments. This provides a foundation for this study both with regard to knowledge gathered and the research methodology used. The usefulness of such a foundation can be seen from Eden's (1992a) remarks on the scarcity of empirical studies on wide-band GDSS and the difficulty of choosing appropriate research designs.

The fifth and last argument for choosing group model building as the focus of this thesis is fundamentally practical. The researcher has practical experience in the use of this method, which is lacking with regard to e.g. soft systems methodology. First-hand experience in applying a method is important, as the intricacies of using a complex method in a real world problem are never completely covered in a written set of steps and guidelines. Eden and Radford (1990) speak about the 'method in use' which can be very different from the 'espoused method' which is featured in the textbooks. Thus, in order to appreciate the options available in adapting a group model building intervention to a particular problem and organisation, practical experience comes in handy. After outlining the arguments for choosing group model building, the following section provides a practical example of its use. In a later section (2.3.6) six distinct types of group model building are described which illustrate a number of different ways in which the method can be applied.

### 2.3.2 A practical example

For the reader not familiar with group model building, it seems useful to introduce the approach with a practical example. In this introduction an artificial case is used that builds on the example of the software product described above. The terms 'intervention' or 'project' are used to refer to the complete process of initial contact with a client to handing over the final model and accompanying report. In addition, the term 'case' is used to refer to the constellation of a modelling project, organisation, and participants. The separate phases of modelling are addressed in more detail in section 2.3.4.

The starting point for a group model building intervention is a problem perceived by one or more managers in an organisation[1]. Although this may seem trivial, the initial problem 'label' functions as a focus for the intervention. In the example of the software product, an initial problem statement might be falling profit. Typically the problematic behaviour will be depicted in a graph over time as in figure below.

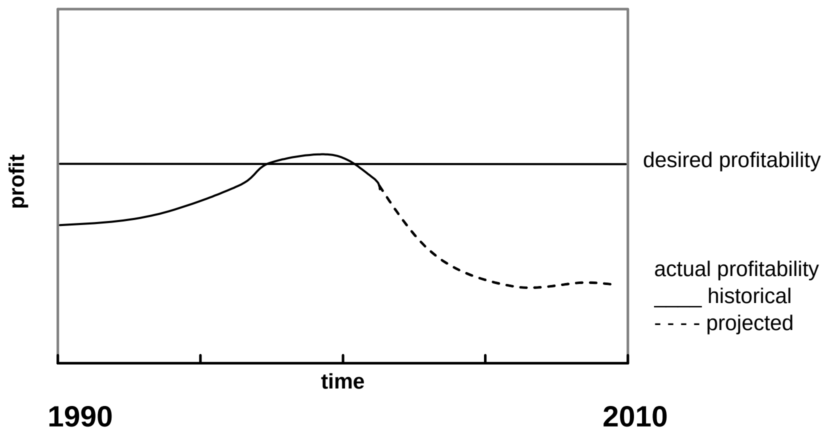


*Figure 2.1 Problem description in graphical form*

The historical problem behaviour is known in system dynamics terms as the reference mode of behaviour. In the graph above, a projection of the behaviour is

[1] This description of a modelling intervention may reflect a number of choices typical for the approach followed by Nijmegen University.

included for the years after 2003. On the basis of the initial problem statement, a decision will be made whether or not group model building is an appropriate method for this problem. This involves questions such as the following: is the problem dynamically complex? Does it entail short or long term effects?

If the method turns out to be suitable for the problem, the next step is to identify participants in the modelling process. Two criteria are employed here. Managers that are knowledgeable about the problem area, as well as managers involved in implementing actions will be asked to participate in the project. A wide variety of viewpoints ensures that no relevant information about the problem is missed, while the power to act is important in implementing decisions. In our simple example participants would probably include managers from both the design, production and marketing department. The gatekeeper, the person who represents the client organisation and probably initiated the project (Richardson and Andersen, 1995), will be among the participants. Typically five to 12 participants are involved in group model building.

After deciding on the applicability of the approach and who to involve, participants are invited for the first meeting. The meeting space will be set up to allow maximum involvement of all participants. From his or her seat, each attendant will be able to see the other participants as well as a whiteboard or projection screen. A group model building session is generally conducted in the so-called chauffeured style, where only the facilitator uses electronic support and projection equipment, while participants do not have access to electronic communication media (Nunamaker et al., 1991)[2]. The central screen or whiteboard will be used to depict the model, as shown in the following figure.

[2] Nunamaker et al. (1991) describe two other modes of interacting with the group: the supported and the interactive style. In the supported style the facilitator again operates the projection equipment, but participants are provided with electronic communication and memory as well. In the interactive style most communication goes through anonymous, parallel electronic channels. Few group model building cases employ the supported or interactive style (but see Rouwette, Vennix and Thijssen, 2000).

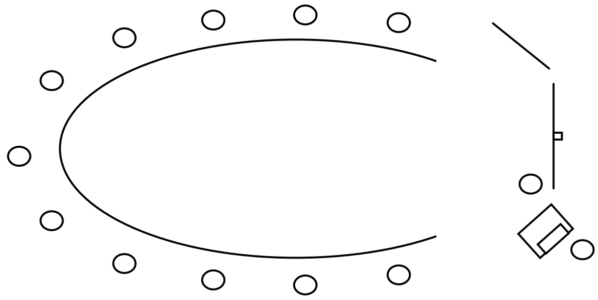

*Figure 2.2 Room layout in a group model building session (adapted from Andersen and Richardson, 1997: 110)*

In the figure, the small circles indicate the persons present in the session. Apart from the participants, there is a facilitator and a recorder. The facilitator has the most important role in the session as he or she guides the group process. The facilitator interacts directly with the group, asking questions and eliciting ideas for constructing the model. The recorder keeps track of the elements of the model. In the figure he is seated behind a computer and the model is projected on the screen in front of the group. A separate whiteboard (upper right hand corner) is used to depict the reference mode of behaviour and record comments or preliminary model structure. As the model is visible to all participants, it serves as a group memory that at each moment reflects the content of the discussion up to that point. The role of liaison between the organisation and the modelling team is performed by the gatekeeper. The gatekeeper is the contact between both parties, and has an important role in the decision which participants to involve in the sessions. Apart from the gatekeeper, the facilitator and the recorder, two other roles are important in a modelling session (Richardson and Andersen, 1995). The process coach functions as an observer and primarily pays attention to the group process. The last role is called the modeller. This person needs to be experienced in system dynamics modelling but might also be an expert in the content area as well. As Richardson and Andersen (1995) point out, all roles are important in group model building but not all of them have to be taken up by a single person. One person might e.g. combine the roles of facilitator and process coach. Taken together, these different roles constitute the facilitation or modelling team.

Typically the first modelling session will start with a brief introduction of the goal of the sessions and the central problem, and the method to be employed. In general it will be emphasised that participants are invited for the sessions on the basis of their expertise or responsibilities in the problem. The facilitator and others interacting with the group will therefore focus on the group process, while participants are content

experts. After the members of the facilitation team and participants have briefly introduced themselves, attention will shift to the problem to be modelled.
If an initial problem statement is agreed on and the reference mode of behaviour identified, the first question the facilitator poses to the group is to write down their ideas on the problem individually. Ideas might include causes, consequences or elements of the problem. One by one, participants are then asked to name their most important idea. Each contribution is noted down on the central screen and clarified. This is in fact similar to the first steps of Nominal Group Technique as explained in section 2.2.3. Prioritisation of elements is usually not included here, as most elements are going to be incorporated in the model. The elements contributed by participants in general have to be reformulated before they are recorded. The reason for this is that system dynamics models are built from variables. Variables are quantities that can increase or decrease over time. In our example, a participant might feel that the low number of products sold during the last months is responsible for the problem of declining profits. In this case, the facilitator would ask if the element can be reformulated as e.g. 'sales volume', as this can decrease or increase and does not already have a value on a scale.

After several rounds of gathering problem variables, a sizable list will have resulted. The construction of the model then starts off by placing the problem variable in the centre of the projection screen. In our case this would be 'profits'. The facilitator then invites participants to take a look at the list of variables and identify causes for changes in the problem variable. A participant might mention 'retail price' as a direct influence on profits. If all participants would agree that there is a relation between retail price and profits, this will be included in the model. In group model building the model is visually depicted using variables and arrows that indicate relations between variables[3]. In this case an arrow will be drawn retail price to profits. Relations can be of two types: positive and negative. A positive relation indicates that both variables change in the same direction. An increase in retail price will lead to an increase in profits, indicating a positive relationship. Variables in a negative relationship change in opposite directions. An increase in costs will decrease profits, indicating a negative relationship.[4]

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[3] This type of model is known as a causal loop diagram. The most frequently used type of model in system dynamics is the stock&flows model which will be addressed in section 2.3.4.

[4] Two remarks need to be made here. First, in system dynamics models relationships indicate connections that hold if all other variables are held constant. If retail price and costs increase at the same time, the resulting effect might be a decrease of profits. However, since all else is assumed unchanged, a positive relation between retail price and profits is included in the model.
Second, a causal loop diagram obscures the difference between physical and information flows and can therefore lead to erroneous conclusions about problem behaviour. A more precise definition of the polarity of a relation is the following (Richardson, 1986: 161): 'A has a positive (negative) influence

After several variables are added, the model might look as follows.

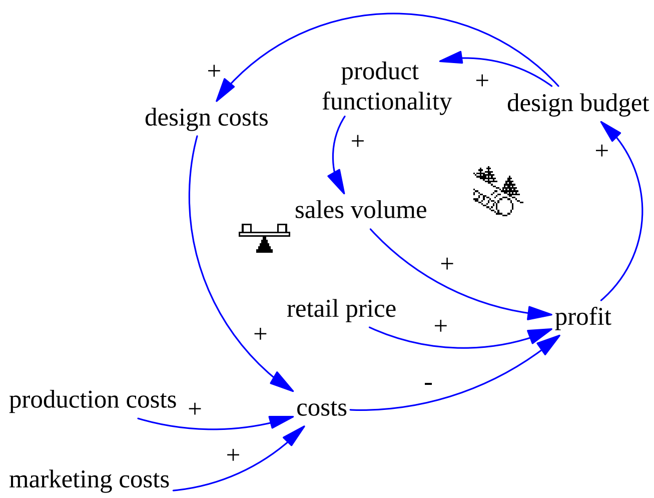


*Figure 2.3 Preliminary model*

The list to the right contains variables that were identified as important problem elements in the brainstorming phase at the start of the session. In the remainder of the sessions, these would be included in the model and related to other variables. Apart from variables and relations the model also contains feedbackloops. Feedbackloops are the main elements of any system dynamics model, as they are primarily responsible for dynamic behaviour. A feedbackloop is formed when a variable A influences other variables in the model, which ultimately have an impact again on variable A. In the model above, it is assumed that an increase in profit results in a direct increase in the design budget. A higher budget allows for increased product functionality, which increases sales volume and finally profit. Starting from an increase in profit, the result is a further increase. This is a so-called positive or self-reinforcing loop, indicated by the snowball rolling down the slope. However, if we assume that the design department uses its complete budget each year, an increased budget will contribute to design costs and lower profits. This is a negative or balancing loop, indicated by the balance symbol.

In the remainder of the session, variables will be taken from the list at the right hand side and placed in the model. At some points a discussion might ensue on the proper place of variables or whether or not a variable has a direct impact. In the figure above, a participant might propose that potential customers weigh product functionality against retail price in assessing product attractiveness. If other

on B, if an increase (decrease) in A results in a value of B which is greater (less) than it would have been had A not changed.'

participants agree, the model would be changed accordingly. In this way the model forms the base for the discussions, and arguments are presented in model terms.
The results of the first session will be captured in a 'workbook' containing the diagram and a short description of the model. The workbook usually also contains questions that serve as a preparation for the following session. While the project progresses, the model will increase in complexity until the group of participants feels that all important variables and relations are included. An important check with regard to completeness is whether the model structure, in particular the loops, can explain the reference mode. A number of other validity tests are discussed in the literature and will be addressed in the following section. The model described above is qualitative, but if possible the model would be quantified and simulated. Simulated model behaviour can then be compared to the historical data contained in the reference mode of behaviour. The ultimate goal of model construction is to identify interventions that change behaviour in the preferred direction: changing the graph of projected behaviour (figure 2.1) in the direction of desired behaviour. This involves identifying the policy levers in the model: those variables that can be influenced by the client organisation. In the model above, the design budget would probably be under control of the client organisation. Instead of increasing the budget with profit, other policies could be devised and tested using the model.
Usually a group model building intervention is closed by handing over the final model and an accompanying report to the client. However, as will be described in the following sections, the creation of a consensus view on the problem and commitment to actions in the problem is a gradual process that takes place during the complete intervention.

The description so far highlighted only the standard and most important elements of a group model building intervention. Vennix (1996) and Andersen and Richardson (1997) describe many alternative techniques that can be employed at crucial stages in the process. The intervention might for instance start with a series of interviews instead of going into a group session directly. Instead of starting the first session with the identification of the problem, a preliminary model might be used to elicit comments from participants. This can be a so-called generic model that applies to a category of problems[5]. Sessions might be structured further using other techniques, in order to allow larger groups to participate. Participants might also be involved in the formalisation stages of the model construction (Andersen and Richardson, 1997; Ford and Sterman, 1998; Mooij et al., 2001).

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[5] An example is Forrester's (1969) *Urban dynamics* which offers a general model on city development that can be applied to specific instances, e.g. Boston, Calcutta or Amsterdam.

In the following section, the main assumptions underlying the system dynamics approach are addressed first. Next, the phases of constructing a model are described in more detail and the facilitation aspect is elaborated further. The section closes with a description of six separate approaches to group model building, that each make their specific choice with regard to the alternative techniques mentioned above.

### 2.3.3 System dynamics assumptions

System dynamics was developed by Jay W. Forrester in the second half of the 1950s, at the Massachusetts Institute of Technology (MIT) in Boston. Forrester first applied system dynamics to the study of industrial organisations, and later to topics such as urban growth, changes in markets and national economies and world dynamics. The use of the method has quickly spread to other application areas and institutes. The system dynamics conferences that have been held yearly since 1985 attract researchers and consultants from all over the world, covering topics in diverse fields such as physics, chemistry, biology, psychology, economy, sociology and management. In these applications Forrester's original emphasis on looking at the interaction between problem elements, instead of singling out separate elements, is still evident. Forrester's (1961: vii) early description of system dynamics (then industrial dynamics) can be applied to each of these topic areas:

> *'Industrial dynamics is a way of studying the behaviour of industrial systems to show how policies, decisions, structure, and delays are interrelated to influence growth and stability. It integrates the separate functional areas of management – marketing, investment, research, personnel, production, and accounting.'*

Likewise, a study on e.g. worker burnout (Homer, 1985) shows how motivational, perceptual and biological aspects interact to produce an increase in hours worked, eventually leading to a burnout. A basic premise of system dynamics is therefore that the characteristics of the whole are more important than the characteristics of individual parts. More specifically, system dynamics is based on four basic assumptions (Vennix, 1996: 45):

- social systems are information- feedback systems;
- structure drives behaviour;
- mathematical models are necessary to trace out dynamic behaviour of a complex problem;
- simulation is needed instead of an analytical solution.

The first assumption captures the idea that the dynamic behaviour of a social system can be explained by its underlying feedback structure. Actors use the information about the structure as input to their decisions, and by implementing their decision influence system behaviour. This creates an interlocked chain of action and information which is also known as a feedbackloop. Richardson (1991: 1) describes a feedbackloop as follows:

> *'The essence of the concept… is a circle of interactions, a closed loop of action and information. The patterns of behaviour of any two variables in such a closed loop are linked, each influencing, and in turn responding to the behaviour of the other.'*

In figure 2.3 examples are given of a positive and a negative loop. As can be seen from Forrester's quote above, in constructing a system dynamics model the modeller will try to identify the loops responsible for the behaviour that is studied. The model boundary is chosen so that all elements responsible for the system's behaviour are included. In other words, the model is causally closed and no influences from outside of the model are necessary for explaining the behaviour being studied (Forrester, 1975: 112). This does not mean that a model is assumed to be materially closed as well. It is not assumed that nothing crosses the boundary between the system described by the model and its environment. However, the assumption is that this exchange is not important for the behaviour being studied[6].

In a model of a social system, many feedbackloops are closed because actors in the system use information on system elements in their decisions. The model depicted in figure 2.3 for instance includes assumptions about an important actor: the customer. It is assumed that if customers perceive that a product's functionality increases, on average more products will be bought. This will increase profits and thereby the design budget. An increased design budget can be used to improve the product's design, which will lead more customers to buy the product, and so on. Thus, decisions of actors within the system have an important influence on the system's behaviour. System dynamics in other words attaches more importance to factors internal to the system than to external influences. 'The premise is that *dynamic behavior is a consequence of system structure*' (Richardson and Pugh, 1981: 15, italics in original).

Since system dynamics models contain many (often non-linear) relations and feedbackloops, it becomes very difficult to predict their behaviour without mathematical simulation. Systems are assumed to consist of interacting feedbackloops, which may change in dominance over time. Consider the spread of a new consumer product, e.g. mobile phones. Initially, starting from a low number of users, the word-of-mouth effect ensures that more and more people will buy a mobile phone. All else being equal, the rate of new purchases will grow as a larger

[6] A personnel model might for example contain hiring of trainees. If the source from which trainees are hired (e.g. the labour market) is not relevant to the model's purpose, this will form the model boundary and the flow of trainees originates from 'outside' the model.

customer base will persuade more and more other consumers to buy the same product. However, if market size is fixed, an increase in the number of customers lowers the number of potential customers (those that have not yet bought the new mobile phone). At a certain point the number of customers and potential customers will be equal, after which the rate of new purchases will fall. So for a limited number of customers a positive loop was dominant: an increase of the number of customers leads to more word-of-mouth, increasing the number of new purchases. However, if the number of actual customers outgrows the number of potential customers, a negative loop becomes dominant: the number of people that can purchase the mobile phone becomes less and less. This example shows another important characteristic of systems from a system dynamic perspective: accumulations (Sterman, 2000; Warren, 2002). Accumulations contain the quantities in the system that can in principle be counted at any moment. Examples are people, money, sales volume, water in a river, or amount of pollution. The combination of accumulations in the system, complex relations between variables and feedback can produce counterintuitive system behaviour. Human decision makers (see section 2.2.2) lack the ability to trace out the dynamic consequences of a complex system structure. System dynamics therefore assumes that mathematical models are necessary to infer the dynamic consequences of system structure.

The last premise of system dynamics is that simulation is needed instead of analytical solutions. System dynamics models consist of a set of equations for which an analytical solution often cannot be found. Instead a numerical solution, or simulation, is needed to solve a model in a series of steps.

### 2.3.4 Phases in building a system dynamics model

In model construction a number of phases can be distinguished, although modelling does not usually proceed in a linear way but involves iterations and rethinking of earlier phases. The phases in system dynamics modelling are the following (Richardson and Pugh, 1981):

1. identification of the problem and model purpose;
2. system conceptualisation;
3. formalisation and parameter estimation;
4. analysis of model behaviour: sensitivity analysis and testing;
5. estimation of model validity or evaluation;
6. policy analysis;
7. model use or implementation.

In the first phase a preliminary problem definition is chosen, in which the problem boundaries, time horizon and the reference mode of behaviour are identified. As

described before, the reference mode is a plot of the behaviour of the most important problem variable over the time horizon studied. It summarises both the level of abstraction chosen for the model as well as the most important behaviour to be simulated, and provides a focus throughout the modelling process.
In the following phase, other concepts central to the problem are identified. Usually these are presented visually and their relationships depicted by arrows. In this way the model structure grows as new variables and relationships are added. The model purpose and system boundary function as a limit to the addition of new variables. An element should be left out of the model if model purpose or behaviour are not affected by its inclusion (Forrester, 1975).
For conceptualisation of the model, two types of diagrams are generally used: causal loop diagrams and stock and flows diagrams. An example of a causal loop diagram is depicted in figure 2.3. While in causal loop diagrams only one type of variable is used, flow diagrams depict two types of variables:

- stocks: entities existing at a certain time period, e.g. supplies, personnel, water in a reservoir;
- flows: entities measured over a time period, e.g. deliveries, recruitments, inflow of water.

Relationships in a stock and flows diagram are separated in physical flows and information flows. In the figure below, information links are depicted with a single and physical flows with a double arrow.

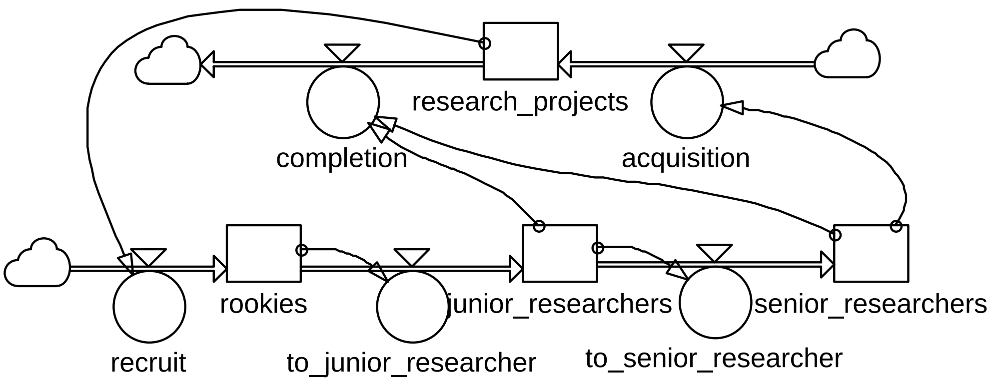


*Figure 2.4 Example of a stock and flows model*

As can be seen in figure 2.4, the physical human resources flow is separated in three stocks: number of rookies, number of junior researchers and number of senior researchers. Recruitment will lead to an increase in the number of rookies. Two other flows influence the number of people in the stocks: rookies may promote to junior researcher and junior researchers may promote to senior researchers. The human resources flow is related to the project flow with information links, for instance

indicating that acquisition of research projects is determined by the number of senior researchers.
In the third phase of modelling, each relationship is translated into a mathematical equation. This might include specifying delays or nonlinearities. The variables in the model are defined more precisely, by indicating their range and numerical value at the start of the simulation period. This step can cause the modeller to backtrack to an earlier phase, if variables or relationships appear to be inconsistent or incompletely defined. After all elements are specified in a mathematical format, the model can be run and behaviour over time analysed.[7]
In the fourth phase, analysis of model behaviour, the goal is a better understanding of model behaviour and the influence of structure on behavioural patterns. Testing includes changing initial parameter values or changing relationships between variables, and observing the effects on model behaviour (Ford, 1999).
The phase of testing the model for its validity is crucial to the modelling process and widely discussed in the literature (see e.g. Forrester and Senge, 1980; Lane, 1995; Barlas, 1996). Model validity concerns the adequacy of the model for representing the problem under study. Forrester and Senge (1980) refer to validation as the process of building confidence in a model. For this they identify a large number of structural and behavioural tests. Confidence in a model increases as more tests are successfully passed. In this phase a balance needs to be struck between adding more detail to the model structure and therefore increasing its complexity, and the ability to understand a model. In the system dynamics literature, this trade-off has led to a number of discussions on model size, the benefits and drawbacks of quantification, and the place of generic model structures. This discussion is addressed in section 2.3.6.
In the policy analysis phase, parameters or larger sections of model structure are changed in order to see their impact on system performance. The goal is to identify changes that steer outcome variables in the preferred direction. In this phase a scenario analysis can be performed by running the model under different conditions for exogenous variables, which clarifies the robustness of policy interventions.

The ultimate goal of a modelling study is the translation of outcomes to the 'real world', i.e. implementation, and bringing about improvements in system performance. In early work by Roberts (1978) and Weil (1980) it is already evident that implementation is an issue that needs to be considered from the first contact

[7] It is important to note that quantification is a debated issue in system dynamics (e.g. Coyle, 2000). Some authors find no problem in limiting themselves to conceptual models only, while others insist on full quantification before problem behaviour can be analysed. This discussion will be taken up in more detail in section 2.3.5 on client involvement in modelling.

with a client. In this view implementation pervades the complete modelling project. It is not so much a separate phase but occurs throughout the process. Vennix (1996: 99) describes it as 'evasive', as it cannot be predicted when and which insights will be produced in modelling. Attention for implementation includes communicating results and ensuring that the client gets first-hand experience of the insights gained in modelling the problem. In the system dynamics literature, the subject of implementation is increasingly discussed in connection to client involvement. In addition to system dynamics, the creation of optimal conditions for client involvement is the second important building block of group model building. Direct involvement of clients in problem analysis is discussed in the literature on facilitation, which is addressed in the following section.

### 2.3.5 Facilitation

Facilitation as it is used in group model building, refers to aiding a group in building a model of their problem (Vennix, 1996: 141). For helping a group in a meeting, three elements might be attended to (Vennix, 1996; see also Schein, 1987):

- content: the subject matter that is discussed;
- procedure or method: the way the subject matter is addressed, e.g. a brainstorm or discussion;
- process: the way group members interact with each other.

A central assumption of facilitation is that the facilitator is neutral with regard to content. He or she focuses on procedure and process, and in that way tries to overcome the limitations of individual and group decision making described in section 2.2. An example is when the facilitator transfers ideas suggested by participants to a whiteboard in front of the group. This procedure of creating a group memory changes the interaction process, by separating ideas from the person who contributed them, and thereby may limit the need for face saving operations. By attending to procedural and process issues, facilitation is expected to make group meetings more effective. The ultimate goal is then not to increase the facilitator's knowledge of the problem, but to increase the insight of the meeting participants (Schein, 1987: 34).

Vennix (1996; 1999) notes that the facilitator's interventions need to be embedded in a particular set of attitudes if they are to be effective. A group memory will e.g. not help in creating an open discussion if the facilitator is not neutral with regard to participants and content. If only some participants' contributions or only ideas of a particular type are transferred to the central whiteboard, it will loose its function as a group memory. Apart from neutrality, Vennix also mentions a helping attitude. The helping attitude boils down to supporting the meeting participants in accomplishing their task. In addition, integrity and authenticity are important. This means that the facilitator is sincere and avoids using tricks. Using tricks is counterproductive as participants will see through them and perceive what is trying to be accomplished. Finally, an enquiring attitude boils down to overcoming the natural tendency to give answers rather than ask questions. By asking questions reflection is encouraged, which hopefully increases insight into the subject being discussed. Although attitudes are critical, skills are required as well for effective facilitation of (modelling) meetings. Vennix (1999) mentions first that the facilitator needs to be well-trained in system dynamics modelling. Although in the description of roles in a modelling session (section 2.3.5) the facilitation role was separated from that of the model builder, a facilitator needs modelling skills in order to be able to formulate the right questions. Second, process structuring skills are needed to facilitate the wide range of activities needed to build a model. This involves amongst others knowledge of group process techniques (e.g. Nominal Group Technique, see section 2.2.3) and when they need to be applied in the modelling process. Since model construction involves bridging differences of opinion, conflict handling skills are a prerequisite as well. The last set of skills is related to an enquiring attitude. This attitude is put into practice by reflective or active listening. By listening, trying to understand, and rephrasing to check whether an idea is understood correctly, the facilitator tries to prevent miscommunication.

The facilitation attitudes and skills described above function as general guidelines for increasing client involvement in modelling. Similarly, the previous sections on system dynamics assumptions and phases in model construction offer only a general description of the group model building approach. System dynamics and facilitation are the two building blocks of group model building, but this framework permits a wide range of choices with regard to techniques, types of models or other aspects of client involvement. In order to get a better understanding of the choices that need to be made in group modelling and the arguments used for deciding between alternatives, the following section describes six different approaches to group model building.

### 2.3.6 Group model building approaches

This section addresses group model building in more detail, by describing different approaches to client involvement. In terms of section 2.2 this section deals with the prescriptive literature on group model building. Vennix (1990: 47) describes three system dynamics based approaches to what he calls interactive policy modelling[8]. In recent contributions, several other approaches to system dynamics modelling with client groups can be found. In total six different participative model building formats can be identified[9]:

1. the reference group (Randers, 1977);
2. the stepwise approach (Wolstenholme, 1992);
3. the strategic forum (Richmond, 1987; 1997);
4. modelling as learning (Lane, 1992);
5. approaches incorporating elements of soft operational research methods;
6. group model building (Richardson and Andersen, 1995; Vennix, 1996; Huz, 1999).

In the following, the general outline of each approach is described.

*Reference group*

In the Reference Group approach (Randers, 1977) participation takes the form of frequent interaction between the modelling team and a group of eight to ten clients. The approach starts with the identification of interest groups, of which representatives are invited to contribute to the modelling effort. The representatives are referred to as referents. In a series of interviews and meetings, the problem to be addressed is defined more specifically. On the basis of this definition and the information gathered in the interviews and meetings, the modelling team develops a preliminary model. In the remainder of the project, the modellers are responsible for further improvements to the model while the referents function as critics. This model is further elaborated in a series of meetings and is at the same time used as a tool for structuring the discussion. In later sessions, model runs are used for developing scenarios. In a scenario discussion the model is run, and results are described and analysed by the modellers. The reference group is then asked to determine to what extent the model's behaviour corresponds to their expectations about reality, and if it does not, to suggest changes. These suggestions can trigger changes in the model structure, initiating a new round in the discussions.

It is clear that in the Reference Group modelling is used as an aid in communication and exchanging views on the problem. The goal is always to make a quantified model but client participation is limited to the conceptualisation phase. No mention

[8] Vennix (1990) describes two other approaches to interactive policy modelling: simulation gaming and the Delphi method. Since this study concentrates on system dynamics modelling, these are not included in the review of participative modelling approaches.

[9] The strategy dynamics approach, as described by Warren (2000; 2002) might well be seen as a participative modelling format. However, there are at present few publications on this approach, and their focus is largely on the content instead of the process of modelling. It is therefore difficult to place strategy dynamics in relation to the other formats and the approach is thus not included here.

is made of client involvement in formalisation issues, but clients are asked to suggest changes in model structure on the basis of observed model behaviour.

*Stepwise approach*

The stepwise approach (Wolstenholme, 1992) is founded on the idea that full quantification of models is not always possible or desirable. The approach starts off with a definition of the problematic behaviour. If possible, this definition is given in the form of a reference mode of behaviour. Modelling starts by roughly sketching the feedback loops responsible for this behaviour. The key variables related to the cause for concern are identified, followed by the system resources connected to these key variables and their initial states. The resources are used to derive the central stocks in the system. From the resources, the resource flows can then be sketched with the associated rates of conversion. Delays are added to these flows if they are significant. Next, organisational boundaries, flows of information and strategies through which the stocks influence the flows, are added. Again, if there are significant delays, these are added to the information linkages. In the final step, information flows and strategies linking different resource flows are added. The steps are repeated until the relevant feedback loops have all been included. Wolstenholme indicates that these steps often provide the insights necessary to infer system behaviour from the structure, which reduces the need for quantification. Models can also be analysed in a qualitative manner.

As in the reference group, the stepwise approach is aimed at fostering insight into the problem. In contrast to the former, the stepwise approach is more explicit on involvement in the specific modelling phases. An attempt is made to involve the client in every stage of modelling and keep the model transparent. The emphasis on transparency probably also functions as a limit on the size of models. In any case Wolstenholme is very explicit with regard to the quantification issue, and underlines the value of qualitative models.

*Strategic forum*

The steps that make up the strategic forum (Richmond, 1987; 1997) provide a detailed insight of how clients are encouraged to participate in modelling. The strategic forum consists of eight steps, of which the first two are conducted before the actual meeting (also called the forum) with the client group. The process begins with interviews prepared by a small questionnaire, in which three issues are addressed: ideas on the current situation, a statement of the vision for the future, and agreement on a preliminary map of the problem. On the basis of the interviews, the modeller constructs an integrated map and accompanying computer model. In the second step the project team designs a number of small group exercises that will be used during the forum. The exercises are aimed at discovering important structural and behavioural elements and are similar to the scenario discussions in the reference group approach. The most important difference is that before simulation results are shown, participants have to 'put a stake in the ground', i.e. they have to make a prediction of model behaviour on the basis of a change in a policy variable and values for connected parameters. The model is then simulated and results are compared with participants' expectations. Discrepancies between predictions and simulations are identified, and might point to inconsistencies in participants' ideas or lead to model improvements. In the following steps the participants meet in a series of workshops. Each workshop opens with an introduction and a big picture discussion. The heart of the session consists of exercises aimed at internal consistency checks, addressing the consistency between the group's mental model and the computer model. As in the other approaches, model structure will be changed if inconsistencies with the participants' ideas on the problem are revealed. In the final phase of policy design, potential consequences of strategic policies are addressed and the existing capability of realizing the strategic objectives. A wrap-up discussion and identification of follow-up activities concludes the strategic forum.

In the strategic forum again an attempt is made to 'take the client by the hand' and make sure that he or she tests assumptions and gains his or her own insights in the process of modelling the problem. Richmond (1997: 146) emphasises that the main purpose of the strategic forum is to check the consistency of strategy. The insights gained by the client therefore frequently lead to changes in strategy or operating policies, but less frequently to changes in objectives or the mission statement. One important element of ensuring an impact on participants' ideas is the (dis)confirmation of expectations on simulation outcomes. Again, the modellers take the foreground in the formalisation phase and specifics of formalisation are not addressed with the client. Clients contribute to this phase mainly by judging the validity of model output.

*Modelling as learning*

Lane (1992) describes a modelling approach developed at Shell International Petroleum, known as modelling as learning. Lane explicitly sets this approach apart from the widely used expert consultancy methodology (e.g. Schein, 1987). His approach also puts strong emphasis on involving decision makers in the modelling process. By showing decision makers the benefits of participation early on in the process, an attempt is made to persuade them to spend time in direct interaction with the model. The approach centres on capturing and expressing the client's ideas, initiating a discussion on the issue with 'no a-priori certainty regarding quantification, or even cause and effect' (1992: 70). The modellers also strive to include both hard as well as soft aspects of the problematic situation. In doing this, it is hoped that the clients' ideas are included in the model and that ownership is created. This is encouraged by making models and model output transparent to participants, helping the client 'to learn whichever techniques are used in a project' (1992: 71). Lane states that the focus throughout the approach is on a process of learning, using such elements as experimentation with the model, testing of assumptions and representing and structuring ideas in a logical way. In a detailed description of a modelling project he describes using a generic model on market growth (Forrester, 1968). As mentioned in section 2.3.2, a generic model is a model that captures the essential elements of a specific category of problems (Lane en Smart, 1996)[10]. An example is Forrester's model, that describes general characteristics of markets and can be applied to different types of markets.

Similar to the other approaches, modelling as learning focuses on fostering communication and insight. Lane accepts qualitative system dynamics as a useful approach in its own right. He also mentions using a generic model for transferring insights from other projects. Concerning the involvement of the client in modelling stages he takes an extreme position, by stating that the client should be able to use all techniques employed in a project.

*Approaches incorporating soft operational research elements*

Modelling as learning is one of the approaches incorporating elements of soft operational research methodologies. Lane and Oliva (1998) describe the theoretical basis for integrating system dynamics and soft systems methodology. Lane (1992), as well as Sancar (1987) and Bentham and De Visscher (1994) use elements of Checkland's (1981) Soft Systems Methodology. One element is for instance the CATWOE analysis, in which a system's Customers, Actors, Transformation, Weltanschauung, Owner and Environment are identified. The cognitive mapping approach (e.g. Eden, 1989) also offers tools and techniques that are used in system dynamics studies. For example, White, Ackroyd and Blakeborough (1994) draw cognitive maps in individual interviews, and merge these into a composite map. The composite map is then the starting point for a system dynamics model.

*Group model building*

The term 'group model building' is more and more used to refer to system dynamics approaches with client involvement broadly. The approach evolved more or less

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[10] Lane and Smart (1996) describe three types of generic structures: canonical situation models, molecules and archetypes. Forrester's (1968) market growth model is an example of the first category as it describes the general structure of markets, and not a specific instance. Molecules refer to specific model components that are used regularly in system dynamics models. A goal seeking structure can for example be used to model inventory management or recruitment of personnel. Both processes can be modelled as a comparison of the actual situation to a target value. The last type of generic structure is an archetype (Senge, 1990). An archetype refers to a particular combination of feedback loops that lead to typical behaviour. The escalation archetype for example, describes how two goal seeking loops can create exponential increase (e.g. an arms race).

simultaneously, with considerable cross-fertilisation of ideas, at SUNY at Albany and Nijmegen University in the Netherlands (see the special issues of European Journal of Operations Research, 1992 and System Dynamics Review, 1997). In an early application, participants were involved in a Delphi study consisting of mailed questionnaires and workbooks, followed by workshops (Vennix, Gubbels, Post and Poppen, 1990). In the dissertations by Verburgh (1994) and Akkermans (1995) a similar approach is used under the name of participative policy modelling and participative business modelling respectively. In its latest version it is a very open approach, which allows for the use of preliminary models or a start from scratch, uses individual interviews, documents and group sessions, qualitative or quantitative modelling and small as well as large models. Vennix (1996; 1999) provides a set of guidelines for choosing among these different approaches, building on and adding to the studies mentioned above. Andersen and Richardson (1997) provide a large number of 'scripts' that can help in setting up modelling projects. The procedures described are a long way from the earlier descriptions of a set of steps that seem to prescribe standard approaches applicable to most modelling projects. Instead, the guidelines offered have more the appearance of tool boxes, from which the appropriate technique can be selected on the basis of problem characteristics and the clients involved.

The following table summarises the way clients are involved in each of the modelling approaches described above.

| | *Phase of involvement* | *Qualitative – quantitative model* | *Use of generic model* | *Size of model* |
|---|---|---|---|---|
| *Reference Group* | Conceptualisation Behavioural analysis | Quantitative | Preliminary model | Not specified |
| *Stepwise approach* | All | Both | Varies | Probably small to guarantee transparency |
| *Strategic Forum* | Conceptualisation Behavioural analysis | Quantitative | Preliminary model | Not specified |
| *Modelling as learning* | All | Both | Possible use of preliminary model | Probably small to guarantee transparency |
| *Soft OR* | Conceptualisation | Qualitative | - | - |
| *Group model building* | All | Both | Varies | Varies |

*Table 2.2 Approaches to system dynamics modelling and dimensions of client involvement*

In this section, six versions of system dynamics modelling with client groups were described. From the description of the steps in these approaches it becomes clear that they share a number of aims. All try to increase the opportunity for exchanging views between participants and learning. However, it is also evident that the way to bring about these goals differs from one approach to another. Some practitioners strictly adhere to the assumption discussed before, that quantification is necessary in order to understand a complex structure. In other approaches qualitative models are found to have benefits in themselves and quantification is not a prerequisite. In addition, the approaches differ in the size of models they use and whether or not a generic structure is employed. Since the term 'group model building' is used more and more to refer to all client oriented approaches, this term will be used in a more general sense. For reasons of simplicity, I will use 'group model building' to refer to client participation in system dynamics modelling throughout the remainder of this study. In this definition the client participates in at least the phases of problem definition and conceptualisation and a wide diversity of techniques might be used to increase participation.
The description of group model building formats provides more detail on how the method is used in practice, and which goals practitioners try to accomplish in different stages of model construction. As mentioned before, the literature discussed in this section is mainly of a prescriptive nature. Applications of group model building to client problems will be described in chapter three.

So far we have been talking about the two central elements of group model building. The first element, system dynamics modelling, was described with regard to its assumptions and phases. The second element, facilitation, was described as a set of attitudes and skills aimed at increasing client involvement in modelling. This section has described six different approaches to combining system dynamics and facilitation. The description of these approaches serves as an introduction to the goals of group model building and the way practitioners go about in realising them. In this research I am concerned with evaluation of group model building. In order to decide on which criteria the intervention will be evaluated, a clear understanding of the steps in the intervention as well as the situation in which it is applied is needed. The foregoing sections described the field of literature (section 2.2) and the intervention to be studied (section 2.3). The next section (2.4) addresses the situation in which group model building is used: complex problems. In section 2.5 the description of the intervention and situation are combined and evaluation criteria identified. Section 2.6 ends this chapter with a summary.

## 2.4 When is group model building used: complex problems

This section describes the situation in which group model building is applied: complex problems. The reason for addressing complex problems in detail, is that the outcome of any intervention will always be a joint result of intervention and the context in which it is used (Pawson and Tilley, 1997). In order to evaluate the application of group model building, it is therefore necessary to take into account the situation in which it is applied. In terms of the literature review of section 2.2, this section deals with descriptive studies on the individual, group, as well as organisational level.

As described in section 2.3.2, the starting point for a system dynamics model is a perceived problem. A problem can be defined as a discrepancy between an actual and a desired state. The sort of problem that lends itself well to analysis is described by Rosenhead (1989: 5):

> *'A 'well-structured problem' will not just have unambiguous objectives, firm constraints, and establishable relationships between causes and effects. It will also, as a result of this specificity, have one clear solution.'*

Rittel and Webber (1973) refer to this as a 'tame' problem, in contrast to the 'wicked' problems that are more difficult to define. Several authors stress that organisational problems are increasingly becoming wicked. Napuk (1993) describes the increasing pace of change in the environment of organisations: new technologies such as ICT or biotechnology have a growing impact on the way organisations operate; globalisation increases competition; market demands are increasingly hard to define as clients ask for more specific goods and services. To this can be added the increasing number of mergers between profit organisations, the growth in number and influence of not-for-profit organisations and the shifts in responsibilities of different levels of government. Mason and Mitroff (1981: 6) point out that these developments cause organisations to become more and more interconnected.

The basic feature of a complex problem is a lack of knowledge on the part of the individual or institutions trying to describe the problem (Vriens, 1998). Mitroff and Sagasti (1973) for instance, describe problems as ill-structured, moderately structured or well-structured problems based on the available knowledge about their components. The number of alternative courses of action, for example, is limited in moderately or well-structured problems, but unlimited in ill-structured problems. Hickson et al. (1986: 10) mention that a problem with precedents is easier to handle, as there is already knowledge about one course of action: '… what was done before can be more safely done again, as long as no obviously disastrous consequences occurred last time.' In addition, uncertainty is lower because previous courses of

action place boundaries on future actions. Previous commitments limit the number of alternatives that need to be considered in subsequent decisions, which prevents 're-opening the whole question and considering all alternatives afresh.' However, Rittel and Webber (1973) point out that decision makers can never be certain that a problem does not have new components, which actually transform it into a different and possibly new class of problems. In their opinion every complex problem is essentially unique as despite a large similarity to another problem, a new characteristic of overriding importance might always turn up. Geurts and Vennix (1989) agree that complex problems present themselves as new, with characteristics not experienced before. Vriens (1998: 272) refers to the available knowledge about a problem as the constructive power for structuring a problem: the ability to identify components in a problem such as variables and relationships, dynamic behaviour and the actors involved. In short, complex problems present themselves to an organisation as something largely new, for which no routines are developed and constructive power at first seems inadequate. Hickson et al. (1986) refer to this as analytical complexity, while Vriens (1998) speaks about instrumental complexity.
In addition to analytical complexity, this type of problems is also complex due to its dynamic behaviour. Feedback between problem variables, nonlinear and delayed relationships make developments over time counterintuitive (Forrester, 1987). Decision making in complex problems requires an iterative process. Checkland (1981) avoids the use of the term 'solution' in this sort of problems, and instead refers to an ongoing debate as complex problems are never solved once and for all. Instead they are the topic of a discussion between stakeholders that is basically endless. Ackoff (1981) speaks about a continuous management of problem messes. Hickson et al. (1986: 249) indicate that the ideal of rationally processing a messy problem, stimulates 'the seeking of information, the compiling of reports and the weighing of possibilities.' However, the scope of the problem make it impossible to reach this ideal and consider all opinions and weigh all information. Bringing the problem structuring process to a close makes simplification unavoidable. Hickson et al. (1986 : 11) put this as follows: 'It is necessary to cut problems down to a size that can be comprehended, by taking account of only a limited amount of information and advice.' The authors find that organisations usually make decisions in a piecemeal fashion, comparing a few alternatives at a time and 'muddle through as safely as possible' (Lindblom, 1959). Muddling through is also in part an answer to the dynamic complexity of problems, as changes in the situation are assessed in a new iteration of the process. Political influences and constraints are considered in an ongoing negotiation (Eden, 1992c).

The broad scope of the problem and the importance of its implications raise the problem to a strategic level (Hickson et al., 1986: 10; Rosenhead, 1989). Only at this

level, the decision which aspects of the problem to concentrate on, can be taken. Ackoff (1981) mentions the difficulty of disentangling a specific problem from the 'mess' of problems an organisation faces, as all complex problems are interrelated (Mason and Mittroff, 1981). In this situation, a number of stakeholders or experts is brought together in trying to structure the problem. Complex problems do not fall neatly within the boundaries of a single organisational department, and expertise from different disciplines has to be brought to bear on the problem. Frequently a team of decision makers from different parts of the organisation is assembled. This adds to the existing complexity by introducing a human relations aspect. The actors involved will bring their own goals to the situation and select different elements as important. The selection processes in individual decision making described in section 2.2.2 operate in complex problems as well. Vennix (1996) mentions a number of experiments showing how selective perception leads to biased information processing. Mason and Mitroff (1981) and Eden et al. (1983) respectively speak about ambiguous problems and personal constructions. Problem owners or experts select different elements as important, because of their backgrounds and positions (Scheper, 1991; Rittel and Webber, 1972: 166). To handle the problem, standard decision making routines still function as an anchor point. Hickson et al. (1986) find that in organisations a 'rationality of control' operates, which both leads to an intention to accommodate the interests of all parties involved and handle even this sort of problems in a rational way. Geurts and Vennix (1989) see the large number of participants in these decisions as the complicating factor, whereas Hickson et al. see their differences in power and goals as the main reason for (social) complexity. The combination of analytical and social complexity creates a so-called 'messy problem' (Ackoff, 1981).
Since the focus of this study is on decision support, an important question is when muddling through is no longer found adequate to handle a decision, and decision support is called in. From the studies of Hickson et al. (1986) and Mintzberg et al. (1976) it appears that changes in decision making routines can only be expected if traditional methods have failed and no satisfactory solution could be found. This conclusion is also reached by Eden (1992a): outside help is asked if a problem is important, complex, and important parties are involved. It appears that only in the most difficult of problems new decision routines are tried out.

In conclusion, messy problems present analytical and social complexity going beyond the constructive powers of stakeholders involved. If muddling through using unsupported decision making does no longer suffice, a decision support method might be used. Hickson et al. (1986) conducted an empirical study on decision making in complex problems, and distinguish between a number of elements of analytical and social complexity. These elements are summarised in the following table.

| *Analytical complexity* | |
|---|---|
| Rarity | Frequency with which similar matters occur |
| Radicality of consequences | How far the decision changed things |
| Seriousness of consequences | How serious it would be for the organisation if things went wrong |
| Diffusion of consequences | How widespread were the decision's effects |
| Endurance of consequences | How far ahead people looked when making the decision |
| Precursiveness | How far the decision was likely to set parameters for subsequent decisions |
| Number of interests involved | Number of internal and external units named as having been involved |
| Diversity of interests involved | Variety of interests |
| Openness to alternatives | How far was there a feeling that the decision had already been made |
| *Social complexity* | |
| Pressure of influence | How great a weight of influence was exerted |
| Intervention | How far external influence was exerted |
| Imbalance | How far the total pressure was uneven across interest units |
| Contention of objectives | How far the interest units that exerted influence did so in opposite directions |

*Table 2.3 Elements of problem complexity, adapted from Hickson et al. (1986: 267)*

Note that the only relations between problem elements mentioned by Hickson et al. are consequences of the problem. Feedback is not included. The number and diversity of interests involved and the openness to alternatives are subsumed under analytical complexity, while differences of goals of stakeholders are included in social complexity. The absence of feedback between problem elements and the inclusion of interests under analytical complexity seem to be related. As follows from the description above, the relation between problem elements is often formed because a decision maker uses information on elements of the system to make a decision which changes the system and closes the loop between action and information. In this way an increase in the number of interests, their diversity or openness to alternative decisions increases the range of possible actions leading to changes in the system. In other words interests and their available choices act as indicators for dynamic complexity and can therefore be subsumed under analytical complexity. Hickson's et al.'s elements of problem complexity are therefore a useful summary of the elements considered by the authors discussed above.

This section has described the situation in which group model building is used. A detailed description of group model building as an intervention in group decision making was given in the previous section (2.3). This puts us in a position to consider the goals of using group model building.

## 2.5 Why group model building is used: intervention goals

### 2.5.1 Overview

In section 2.3.6 a number of specific approaches to group model building were described. Most of this prescriptive literature provide details on the reasons or goals for using the methods. In addition, Huz et al. (1997) propose a comprehensive framework for evaluating system dynamics modelling. The following table summarises these goals at four levels: individual, group, organisational and methodological.

| | |
|---|---|
| individual | positive reaction<br>mental model refinement<br>commitment<br>behavioural change |
| group | increased quality of communication<br>creation of a common language<br>consensus and alignment |
| organisation | system changes<br>system improvement or results |
| method | further use<br>efficiency |

*Table 2.4 Outcomes of group model building*

At the individual level four goals can be identified. Several authors stress the importance of clients' reactions to the model or other elements of the intervention, e.g. trust in the modeller (Lane, 1992). All approaches underline the importance of learning; clients are encouraged to take a broader perspective on the problem modelled. In the system dynamics literature, insight is often equated to mental model refinement. Commitment to results and the resulting changes in behaviour are also widely agreed on as an important goal of client involvement. In the modelling phases described in section 2.3.4, implementation of system changes constitutes the last step,

although more and more authors describe it as a goal pervading the complete process of model construction (e.g. Roberts, 1978; Vennix, 1996). It seems logical to expect system improvement to be a goal even higher in the hierarchy, for which commitment and implementation are a prerequisite. Behavioural change is the equivalent of implementation on the individual level.
Discussions on common language and communication are relatively scarce in the methodological literature in system dynamics. If mentioned, they seem to be considered one of the elements affecting insight. Insight, in the form of a mental model of problem being modelled, has been central to the field from its initiation (Forrester, 1961). The impact of group model building on consensus and alignment of mental models has been the central topic of a recent dissertation (Huz, 1999). The methodological goals in the table above are less often discussed. Further use refers to the application of system dynamics to new problems, while efficiency of (elements of) the method is concerned with the results of group model building in comparison to other methods, including unsupported decision making. Further use and efficiency almost have the role of side-effects, although one of the goals of Lane's (1992) approach to modelling is to learn participants about the techniques used.

In conclusion, there seems to be an implicit ordering of group model goals which boils down to the following. The intervention is expected to lead to higher quality of communication, which (among others by increasing shared language and in conjunction with reaction-based variables) leads to changes in mental models and an increase in mental model alignment. Changes in mental models and alignment are expected to yield commitment to conclusions, behavioural change in the form of implementation of results, and finally system improvement. In the broader evaluation literature, a distinction is often made between four levels of goals: reaction, learning, behaviour and results (Kirkpatrick, 1959; Alliger en Janak, 1989). Reactions refer to emotional responses (e.g. satisfaction), while learning involves cognitive changes. Behaviour refers to changes in individual actions, which are a prerequisite for any improvement in effectiveness or efficiency of the system considered (results). These levels seem to match our ordering of goals of group model building with regard to the individual level. Alliger and Janak (1989) point out that the relations between levels are not straightforward in the sense that positive reactions lead to learning, which in turn determines behavioural change leading to positive results. On the basis of a review of evaluations of interventions, they conclude that reaction is not correlated to any of the other levels. Learning, behaviour and results are related in complex ways. When considering goals of group model building, the presence of goals at the group level (communication, common language and consensus) further complicates the picture.

Before turning to relations between variables, I will first describe the main goals of group model building in more detail. Since reaction does not have a straightforward relation to any of the other evaluation levels, this will not be considered a main goal of modelling[11]. Commitment and behavioural change are closely related to the (more widely discussed) topics of system changes and results, and will therefore be discussed in one section. The same argument applies to communication and common language, which are discussed in one section as well. Since I am primarily interested in the effects of modelling with regard to the problem being addressed, methodological goals (efficiency and further use) will also not be considered among the main goals of modelling interventions. In summary, the main goals of modelling are considered to be the following:

- system changes and system improvement;
- mental model refinement;
- consensus and alignment;
- increased quality of communication and creation of a common language.

In the following sections these four topics are addressed in turn. Discussions on these issues are mainly found in the descriptive literature on system dynamics and GDSS. In section 2.5.6 relations between goals and mechanism elements are discussed.

### 2.5.2 System changes and system improvement

Implementation of system changes was described in section 2.3.4 as the final stage of the modelling process. The system dynamics literature reports many cases of changes in organisational policies, e.g. a decision by a government department on subsidies (Vennix, 1995), aligning tasks in a service organisation (Cavaleri and Sterman, 1997) or increasing inter-organisational cooperation (Huz, 1999). Many studies report on results of system changes as well, e.g. an increase in production and logistic performance (Akkermans, 1992), a more supportive organisational culture (Bentham and De Visscher, 1994) or a settlement in a court case (Cooper, 1980).

In most cases the decision to implement system changes is made by a group of managers. In the modelling projects an effort is made to involve those managers that have the power to implement changes. Implementation of system changes is therefore closely related to changing behaviour of participants. This can e.g. be seen in the case reported by Vennix (1995) where the decision whether or not to continue subsidies can only be made with the consent of all department managers. Before the

[11] Reactions as discussed in the system dynamics literature seem to refer to emotional responses. In this sense reaction does have a similarity to several variables in the conceptual model described in chapter four. See for example the definition of attitude in section 4.3.1 and the peripheral route to persuasion described in section 4.4. However, since the main focus of this thesis is on cognitive factors, emotional responses are outside of the scope of this study.

intervention some managers were reluctant to agree to a request for further subsidies. After participating in model sessions these managers decided to sign the request. In this case a change on the organisational level can almost directly be traced to changes on the individual level. Individual decisions are embedded in a set of personal opinions, which in the system dynamics literature are often referred to as mental models.

### 2.5.3 Mental models

The importance of the term mental models is captured by the statement by Geurts and Vennix (1989: 58) who regard mental models as the alpha and omega of modelling and policy analysis. Doyle and Ford (1998: 4) mention why this should be so:

> *'Mental models are thus the stock in trade of research and practice in system dynamics: they are the "product" that modelers take from students and clients, disassemble, reconfigure, add to, subtract from, and return with value added.'*

In their article, Doyle and Ford recount the widely differing – and sometimes contradictory – definitions of mental models available in the system dynamics literature and related fields such as cognitive science and psychology. They note that the definitions in system dynamics have developed largely in isolation from work on mental models in other disciplines. The definitions used by system dynamicists vary widely with regard to characteristics such as stability, complexity, elements (definitions refer to concepts, beliefs, images and perceptions alternatively) and whether they refer to a single or multiple types of mental constructs. Most definitions do not include a description of all or most of these characteristics and are so broad that they might as well refer to concepts such as 'psychology' or 'cognition' (Doyle and Ford (1998: 15). However, definitions in psychology and cognitive science do not contain more specific or detailed ideas. Doyle and Ford's solution is to unbundle the concept and separate it into distinct components. After a 'friendly amendment' by Lane (1999) their revised definition reads as follows (Doyle and Ford, 1999: 414):

> *'A mental model of a dynamic system is a relatively enduring and accessible, but limited, internal conceptual representation of an external system (historical, existing or projected) whose structure is analogous to the perceived structure of that system.'*

The main elements of the definition can be described as follows. Doyle and Ford use the term 'model' because they want to avoid both the completeness suggested by 'theory' and the confidence implied by using 'beliefs'. In their opinion the core of a mental model is stored in long-term memory and relatively enduring, although details might be altered in a time period of seconds or minutes. They restrict the concept to cognitive structures that are relatively easy brought into consciousness, referring to other structures as 'implicit models'. A mental model is in their opinion a precompiled and relatively integrated subunit of information, limited enough to be implemented in short-term memory. It is a cognitive construct and therefore internal, while externalised representations can be referred to as 'cognitive maps'. The model predominantly consists of concepts, because the abstract social situations studied in system dynamics do not lend themselves well to picture-like representations. It is a structure storing information and not a mental process working on information.

The reference to an external system was commented on by Lane (1999). Lane considers it important to emphasise the clear link system dynamics established between a model and its reference system, because this aspect sets the field apart from the soft operational research community (Lane and Oliva, 1998). However, Lane notes that system dynamics models can be and are built of systems that are not (yet) existing, e.g. because they represent ideal or desirable situations. Doyle and Ford (1999) agree to this point and change the definition to include 'projected' systems. Equally important is the fact that they do not include concepts that refer only to a cognitive structure and do not have any reference outside a human mind in their definition. Goals as contained in the ends model mentioned by Richardson et al. (1994) and constructs such as attitudes (Eagly and Chaiken, 1993) are considered to be stored separately in long term memory.

Indeed Doyle and Ford speak of a 'mental model of a dynamic system' in order to underline the difference with other representations, which include goals or attitudes but also models of the actions available to influence a system. A representation of prerequisites for actions is referred to by Richardson et al. (1994) as a means model. The mental model of a dynamic system is equal to their means/ends model, functioning in tandem with at least two other types of models (means models and ends models). By using the term 'structure of a mental model', Doyle and Ford imply that the knowledge is organised, although the precise nature of the nodes and links that make up the model have yet to be confirmed in research.

The last element of Doyle and Ford's definition is the similarity of the cognitive structure to the perceived structure of the system. Here they stress again that mental models are simplifications; the mental model *attempts* to preserve the reference structure but includes many errors and omissions.

In sum, many system dynamicists see mental models as enduring internal representations of a dynamic system. Goals and means, although important in decision making, are taken to be stored as separate representations. In this study I will use the term mental model in a broader sense and include each of these elements: dynamic systems or means/ends, means and ends. An important goal of modelling is to enrich the mental model of participants in the modelling process with regard to all of the three aspects. A system dynamics model contains and combines ideas of all participants in the modelling process, and therefore contributes to a shared understanding of the problem. Participants are in other words expected to change their mental models in the same direction. This is discussed in the system dynamics literature under the headers of consensus or alignment.

### 2.5.4 Consensus and alignment

Another important goal of group model building, which is less widely discussed in the system dynamics literature, is consensus or mental model alignment. It is often assumed that in a group that has reached a shared consensus, each group member has adopted the shared group model (Doyle et al., 1996). However, Doyle et al. emphasise that these concepts are not similar, and the extent to which models are shared or aligned can only be estimated by comaring individual mental models. Two dissertations on effects of participative system dynamics modelling include measurements of consensus. Verburgh (1994) assesses shared understanding by looking at changes in form and content of participants' problem descriptions. Before and after the modelling sessions, participants are asked to write a short text on the effect of a specific intervention on a subsector of the system under study. Answers are coded into cognitive maps by identifying concepts, relationships, time-indicators and delays. An increase in shared understanding of content is indicated by a decrease in variance of the number of concepts used between pretest and posttest. Relationships, loops, time-indicators and delays are used in a similar fashion to determine the degree of shared understanding of format. One element of shared understanding with regard to format of knowledge, is the variance in the number of feedbackloops in participants' policy maps. Verburgh's measurement of shared understanding focuses exclusively on the *number* of concepts and other elements of policy maps. The conceptualisation of shared understanding used by Huz (1999) is different in the sense that it takes into account overlap in content of concepts as well. In his dissertation, Huz (1999: 2) looks at shared understanding in the form of alignment, which he defines as 'movement by group members toward a shared vision that is not coerced or mandated.' Huz surveys the systems thinking and organisational learning literature, showing that alignment is often considered the basis for organisational action. Other related concepts are common or shared understanding, a common vision or shared mental models. Huz concludes that the common element in these definitions, most clearly captured by Senge (1990), is the reduction of variability in thought among individuals[12]. He then specifies the concept

[12] Reduction of variability in thought in this sense does not refer to an absolute agreement of opinions. If taken too far, this might reduce the organisation's ability to cope with changes (variance) and thereby threaten its viability. Rather, a situation in which opinions diverge so widely that it is impossible to agree on a shared action plan should be taken as a point of departure. In this situation,

further by using Richardson et al.'s (1994) three mental model types. In his research Huz concentrates on the goals model and means model, assessing participants' attitudes towards key goals and potential means to achieve desired changes in the problem modelled. Combining this with the definition offered before shows that movement toward a shared vision is translated here as agreement on means and ends.

Two authors that look into the content of cognitive concepts are Faber (1994) and Scheper (1991). In line with the separation of problem knowledge in different mental model formats, Faber (1994) points to another distinction between cognitive structures. In a comment on the Verburgh's (1994) study, he discusses the possibility of managers treating their individual problem perceptions and the consensus view as two separate cognitive structures. This would mean that managers distinguish between their personally preferred definition and the problem definition that is feasible collectively. Following this line of reasoning, a collective model is not merely the overlap between separate mental models but stored separately in individual memory. Scheper (1991) also looks at the definition or meaning of cognitive elements. Scheper uses the notion of the semantic network and semiotics (Eco, 1976; 1984) to define shared meaning. In this view, two persons attribute the same meaning to a topic if it relates to similar concepts and relationships in their semantic networks.

In sum, consensus is defined alternatively as a. shared understanding, an overlap in concepts and types of relationships; b. alignment, agreement on the content of concepts, i.e. means and ends; c. a separately stored representation of consensus, the subjective interpretation of the consensus view; or d. shared meaning, similarity between the meaning of concepts. In chapter four, on the conceptual framework for this study, consensus is addressed again and a definition chosen. In order for consensus to emerge, it is not sufficient that participants are confronted with a model but also that they communicate about their problem perceptions (Scheper, 1991). This is discussed in the following section as yet another goal of group model building.

### 2.5.5 Communication and common language

In the system dynamics literature the expectation can be found that system dynamics serves as a uniform platform for communication (e.g. Richmond, 1987: 132). In many cases persons from different departments in a large organisation, for instance finance or research and development, can be said to use different languages to describe organisational problems. By using terms such as stocks and flows that are independent from the specific content, system dynamicists expect to be able to bridge

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increased convergence of thought can be beneficial. It seems that the relation between variability of differences between departments. Shields (2002) reports on an experimental study on the role of communication in group model building[13]. A definition of what constitutes communication can however not be found in the system dynamics literature.

A common definition in the broader GDSS field is the following: 'the process and focus of information exchange in the group' (Pinsonneault and Kraemer, 1990: 150). A more elaborate definition is provided by Scheper (1991). Scheper takes the classical communication model developed by Shannon and Weaver (1949) as his point of departure. In the Shannon and Weaver model, a sender directs a message through some channel to an addressee. In this view, understanding of message content is unproblematic. Sender and receiver infer the same meaning from the message; they use identical codes. However, in social contexts it is not always rational to expect communication partners to use the same codes. Following Eco (1976), Scheper equips the communication partners with semantic codes. A further simplification in the Shannon and Weaver model is the transmission of the message. According to Scheper, a more precise description of this step of the communication process is to refer to transmission of a *signal*. Before the addressee can understand what message is being sent, she first has to acknowledge that the signals are conveying a meaning. Scheper gives the example of a radio message. A radio transmitting all sorts of noise might not be recognised as sending a message. If the transmission is conceived of as a random variety of buzzing sounds, it will not mean anything to a listener. If however the listener realizes that some of the sounds occur at regular intervals, she might conclude that the signal transmitted is a Morse code that does convey a meaningful message. An interesting parallel might be seen in modern forms of music, as perceived by an audience unaccustomed to its style. Scheper's communication model includes a meta-code, which is used to decode a 'transmission as message' (the Morse code) from a 'transmission as signal' (the random noise). After applying the meta-code, the semantic code is used to infer meaning from a message. Which semantic code is used depends on circumstantial and contextual selections. The selection of a code has to be made by both the sender and the addressee. It might be clear from the discussion so far, that a message can be differently interpreted if the two parties in the communication use different codes. This underlines the importance of a shared or common language. By using a uniform

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thought and organisational effectiveness is non-linear.

[13] Shields uses the term 'group dynamics', which she defines as 'the observable level of group debate and discussion in the group problem solving forum' (2002: 10). Group dynamics is then operationalised as the number of participants' comments with regard to strategy, comments on the rationale for strategies, proposals for process procedures and attempts at facilitating the group process. This definition and operationalisation highlight the similarity to communication as it is defined in this section. Since Scheper's (1991) definition allows for differences in semantic codes, the latter will be used in this study.

platform for communication, a similar interpretation of messages becomes more likely, which facilitates communication. Creating a common language can therefore be seen as one element of increasing communication quality.

This section on communication and common language concludes the description of separate modelling goals. In the next section, the prescriptive literature on relations between goals and intervention elements are addressed.

### 2.5.6 Relations between goals and group model building elements

In section 2.5.1 an overview of goals of group model building was given. Ultimately, group modelling was expected to lead to system improvements, brought about by implementing project conclusions. Implementation in turn was fostered by refining mental models and consensus. The quality of communication between participants in a modelling project was expected to contribute to mental model refinement and creation of consensus. After the description of the main goals in the foregoing sections, we are now in a position to consider these relations in more detail.

How the effects of group model building are brought about, is still a debated issue in the system dynamics community. Andersen et al. (1997) list seven different hypotheses about the way in which outcomes of modelling are created. Two examples are the chunking hypothesis (the effects of modelling are brought about by the big chunks of insights generated in the project) and the group communication climate hypothesis (the quality of communication determines the outcome of a modelling project). A comprehensive framework in which these different variables are related, can not be found in the literature. In the following the scattered insights in the system dynamics literature as well as the broader GDSS literature are used to deduct ideas on the relations between modelling goals and elements.
The expected impact of the intervention on communication is described in a number of studies. In section 2.2.3 it was described how GDSS (including group model building) aim to overcome some of the drawbacks of communication in freely interacting groups. In a freely interacting group communication is often hindered because different phases of the decision making process are mixed up, e.g. production and evaluation of information. In general this leads to a lower number of ideas compared to the situation where phases are separated (Delbecq et al., 1975). In group model building production and evaluation of ideas are separated to increase effectiveness of group decision making. Vennix (1999) sees facilitation as a guard against these and other detrimental elements of the interaction process. In section 2.3.5 it was described how a facilitator increases the quality of communication, for instance by limiting the need for face saving operations. By asking questions for

clarification instead of trying to press his view, the facilitator enacts the behaviour expected and increases quality of communication. Morecroft (1992) and Shields (2001; 2002) describe how the facilitator increases quality of communication by helping to elicit knowledge, mediate power relationships and increase the depth of communication. In addition to facilitation, modelling has an impact on communication quality as well. The impact of modelling on communication can be seen from Richmond's (1987) assertion that system dynamics operates as a uniform language, promoting a similar interpretation of messages. As noted in the last section, creation of a common language is subsumed under increasing quality of communication.

The mainstream of publications on system dynamics methodology is however not concerned with group decision making or facilitation, but instead focuses on model content: analysis of structure and behavioural patterns, validation and testing, and policy experimentation. The system dynamics model and participants' mental models are expected to be closely related. Mental model refinement is often equated with increasing insight into the structure and behaviour of a reference system (Andersen et al., 1997: 190). Most system dynamicists would probably consider the development and analysis of a model as the main vehicle for bringing about insight. This resembles the view of models as transitional objects or items people can play with in order to refine their understanding of a particular subject (Morecroft, 1992). Shields (2002: 5) asserts that modelling might provide input for the visual part of working memory, while the facilitated discussion might influence a separate part of working memory, i.e. the part dealing with phonetic information. Since both parts work in cooperation, influencing visual as well as the phonetic parts can increase the impact on learning. Lane (1992: 74) sees the function of models as making the view of participants more coherent: '…goals which seemed reasonable when only part of the system was viewed are seen as inconsistent or impossible in the context of the whole system.' This points to an impact of modelling on the ends model (Richardson et al., 1994). Vennix (1996; 1999) relates the construction of a system dynamics model to the individual perception and retention processes. The human information processing capacity cannot deal adequately with complex systems, as humans are biased in their decision making and fail to see feedback processes. A model helps participants to structure the complex problem and enables them to put their problem definitions to the test. The influence of the social context on the formation of mental models makes explicit testing of mental models crucial. People may reinforce each others' beliefs leading to shared beliefs which often are no more than illusions, e.g. Hall's (1984) departmental bias. Andersen et al. (1994: 13) distinguish two ways in which modelling might impact understanding: by increasing knowledge on the complexity of a system (design logic) and by fostering insight into strategy selection (operator logic). Design logic is defined as follows:

*'The design logic emphasizes the need to create more elaborate, causally sophisticated, and feedback-sensitive cognitive models of means-ends effects. Only by understanding the complexity of the system that they are managing will managers be better able to improve system performance.'*

Apart from design logic, models promote operator logic as well. The operator logic predicts that detailed understanding of the system design is not enough and that selection of effective strategies needs to be supported directly, by giving strategic insights in the form of chunks or heuristics. A heuristic captures the responses of a system to a particular intervention, and does not include detailed insight into the system's structure. Following this reasoning, the understanding of the dynamical system is largely a means to gain confidence, of which the details are forgotten when it comes to implementation (Andersen et al., 1997: 195). Modelling in other words helps to refine mental models with regard to understanding of system structure and responses of the system to interventions.

Two other effects of model construction are described by Vennix (1996; 1999). Vennix elaborates on the role of the model in aligning mental models. The use of a model allows individual partial models to be combined. In addition, the model functions as a group memory, providing an overview of the discussion so far.

Figure 2.5 summarises the relations between group model building goals and elements discussed in the prescriptive literature. Facilitation improves communication quality, amongst others because a facilitator structures the discussion and asks for clarification. Facilitation, in conjunction with communication, helps in creating consensus since all participants are encouraged to participate in the process of modelling. Model building has an impact on communication, mental models and consensus, as it structures information and shows the common elements in participants' ideas. Mental models are influenced by the information exchanged in the communication between participants as well. Mental models, representing individual ideas on the problem, together with the group's consensus view, impact implementation of actions and ultimately system improvement.

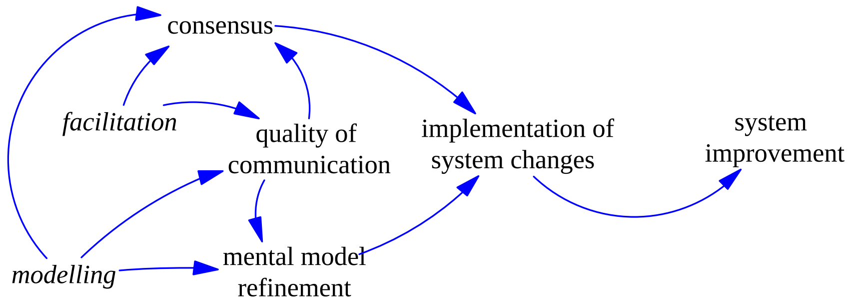


*Figure 2.5 Conceptual model of the relations between goals and elements of group model building (intervention elements are depicted in* italics*)*

This concludes the description of group model building goals and relations between goals. The next section summarises this chapter's conclusions on the intervention.

## 2.6 Summary of group model building context, mechanism and outcome

In this chapter the intervention method to be studied was addressed. Starting from a general overview of decision making literature, group model building was selected as the topic for this study. Group model building was described by giving a practical example of a modelling project and discussing its two main elements: system dynamics modelling and facilitation. System dynamics assumes that problematic behaviour can be adequately explained by the underlying feedback structure. In order to understand its structure, the problem needs to be captured in a model. Facilitation is used to enable problem owners (managers) to participate in model construction. Participation in modelling is expected to increase managers' insight into the problem and support for the project's conclusions. System dynamics and facilitation offer a toolkit with a diverse set of techniques for involving managers in modelling. Six different approaches were described that each emphasise particular aspects of client involvement. The main aspects on which approaches differ are the following:

- modelling phase in which the client is involved;
- use of a qualitative or quantitative model;
- use of a generic model;
- size of model.

Each approach combines elements of system dynamics and facilitation in a particular way but shares most of the basic assumptions in these fields. The final assumption of system dynamics, mathematical models are necessary to fully understand dynamic behaviour, is however interpreted in different ways. The reference group and strategic forum seem to find quantification a necessity, while the stepwise approach, soft operational research approaches and group model building might end with a qualitative model. Another common element of the various approaches to group model building is that they are all applied to complex problems in organisations. Managers involved in these analytically and socially complex situations act on the basis of their subjective views on the problem, making it necessary for the modeller to elicit and integrate diverse opinions. The following main aims of group model building in these situations were identified: system changes and system improvement, refinement of mental models, creation of consensus and increasing the quality of communication. In the last section these goals were related to one another and to the elements of group modelling.

Above elements and goals of group model building were identified. Since the subject of this research is the application of group model building to a complex organisational problem, it is important to realise that outcomes of a modelling project depend on both contextual (problem and organisation) and intervention characteristics. For other GDSS the situation is comparable. McGrath and Hollingshead (1994: 78) start their review of results of group decision support technology by pointing out that outcomes will inevitably be a joint function of contextual and intervention characteristics. After reviewing Delphi studies, Rowe and Wright's (1999) stress that the question whether a technique is effective cannot be answered without knowing how they impact decision making groups. They conclude that (1999: 373): 'We need to understand the underlying processes of techniques before we can hope to determine their contingent utilities.' Wolfe (1976) reaches a similar conclusion with regard to gaming simulations. According to Wolfe, effectiveness research must deal with all situational variables that have an impact on the simulation, such as simulator design characteristics, characteristics of the setting of the simulator (e.g. duration and learning objectives), player and group characteristics and characteristics of the facilitator(s) of the game. In a more general sense, Pawson and Tilley (1997) argue that a realistic comparison of evaluation studies boils down to discovering which combinations of mechanism and context lead to which outcomes. Context is used in a very wide sense here, referring to all conditions that influence the causal mechanism at work in the intervention (Pawson and Tilley, 1997: 69), e.g. social conditions, rules, norms, values and interrelationships. Context is therefore not limited to the objective characteristics of the organisation in which group model building is used. In this research the context is formed by an organisational problem that is both analytically and socially complex. I will use the term 'client' to refer to the constellation of individual, group and organisational characteristics that determine how the complex problem is handled. As the literature reviewed so far did not offer a comprehensive theory on organisational decision making, it is difficult to determine the important elements of context at this point. The central contextual variables will be specified at a later point (see section 4.2.4). The main elements of mechanism and outcome were addressed above. The total configuration is shown in the following table.

| *Context* | | *Mechanism* | | *Outcome* |
|---|---|---|---|---|
| Client<br>Messy problem: analytical and social complexity | + | Group model building: modelling and facilitation | = | System changes and system improvement; creation of consensus; refinement of mental models; increased quality of communication |

*Table 2.5 Basic context, mechanism and outcome elements of group model building*

In order to identify relevant criteria for the evaluation of group model building, two steps seem to be necessary. First, the descriptive literature on group model building needs to be addressed. This chapter has focussed on the prescriptive literature, drawing out goals and guidelines for participation in model construction. Before a focus for this thesis can be selected, outcomes that are found regularly in group model building evaluations will need to be identified. Results that are well-established in the literature can serve as a foundation for future research. An additional aim is to identify outcomes that are still under discussion so that this research can make a relevant contribution to the literature. This will be the topic of chapter three.
Second, in this chapter context, mechanism and outcome elements in the table above were considered in isolation. According to Pawson and Tilley (1997) an idea of the relation between elements is useful for directing research. Consider for example the following modelling project. In a highly political situation the modeller chooses a qualitative rather than a quantitative model, since she expects a qualitative model to help in separating differences of interpretation from differences in opinions or goals. In addition, quantification is difficult since most data are in dispute. In a context of less political struggle, more time in the project might be spent on gathering data and including more details in the model, which constitute further tests of the conclusions. Thus, in order to evaluate outcome (the effectiveness of group model building) it is relevant to know the project context (how political the problem was) and mechanism (the decisions of the modeller). In effect these considerations are the beginning of a basic theory of how group model building affects participants. The overview of group model building studies in chapter three will increase the insight into relations between context, mechanism and outcomes. These relations are then combined into a conceptual framework on group model building effectiveness. This is addressed in chapter four.

# Chapter 3 Group model building effectiveness studies[14]

## 3.1 Introduction

This chapter addresses descriptive studies of group model building applications. In chapter two prescriptive studies were described, that provide methodological guidelines on how to set up and conduct a group modelling study. Group model building was expected to achieve several outcomes at the individual, group, organisational and methodological level. The main goals were implementation of system changes and system improvement, creation of consensus, fostering quality of communication and refinement of mental models. In order to identify relevant questions for the empirical part of this research, the status of the literature on the evaluation of group model building will need to be considered. Effects of modelling which are well-established in the literature can serve as a base for the current research. Therefore in this chapter case reports on applications of modelling are addressed. From the literature 107 cases were identified that provide details on the modelling process and the assessment of results. In this chapter a meta analysis of findings of these studies is reported for three reasons. First, to provide a review of descriptive studies into group model building, with regard to the contexts in which the approach is applied, the ways in which modelling is used and the outcomes assessed.

Second, to identify robust outcomes of group model building interventions. Probably the most important reason for building a model is the expectation of learning. Our intuition tells us that modelling of a problem should result in an increase of insight into the problem. However, at this moment there is scant evidence to back up this intuition. In-depth studies of learning in microworlds show only modest effects on learning at best (Vennix, 1990; Doyle et al., 1998; Größler, 2000). Andersen et al. (1997: 188) conclude that:

> *'Even after extensive training in modelling, although individual learning occurred, no real improvement of participants' mental models, in terms of entertaining more feedbackloops or more elaborate causal relationships, could be established.'*

Third, section 2.6 described how outcomes of group model building interventions will always be a joint function of contextual and intervention characteristics. In addition to identifying general results of modelling, the more specific question can be asked whether certain combinations of context and modelling techniques reliably produce particular outcomes. Context was used in a broad sense, referring not only to objective characteristics of the organisation where group model building is used, but to all conditions that impact the effect of the intervention (Pawson and Tilley,

[14] This chapter is based on an article by Rouwette, Vennix and Van Mullekom (2002).

1997: 69). In other words if the same techniques for modelling would be used in different contexts, different outcomes can be expected. The context for group model building is formed by a complex organisational problem, but the literature reviewed so far has not specified which organisational or problem elements are especially relevant for shaping modelling outcomes. Thus, establishing the relationship between modelling elements and outcomes is not straightforward. The third goal is therefore to produce meaningful and potentially robust patterns of intervention elements, contexts and outcomes.

## 3.2 Method: selection of cases and construction of the database

A literature search was conducted for publications on group model building in the System Dynamics Conference Proceedings (1981 to 1999), the System Dynamics Review (1985 to Winter 1999), and publications on system dynamics by Productivity Press. A request for additional publications was placed to the system dynamics discussion list. Each source was reviewed by a researcher, who subsequently selected relevant publications. Publications were deemed relevant if (a) they described a system dynamics modelling project involving a client team in at least the stage of conceptualisation, and (b) any empirical results on its effectiveness were described. In total, 86 publications describing 107 cases were catalogued[15] (see appendix A).

The procedure for gathering cases may have produced a bias, either because cases were erroneously excluded, or because cases were reported in other sources than the ones used here. In addition, an additional bias may be introduced because not all group model building interventions will be published due to a variety of reasons. The client may for instance prevent publication because of proprietary right, something one would expect to happen more often in profit organisations. Two factors plead against this potential bias. First, the emergence of a special consultancy track at System Dynamics Conferences, in which mainly cases in profit organisations are discussed. Second, the fact that a total of 60 percent of the cases in this meta-evaluation was conducted in a profit setting.

Another reason for not publishing a case may be that the person conducting the intervention is reluctant to publish because the intervention was largely unsuccessful. Indeed few descriptions of unsuccessful interventions were found. It could thus be that unsuccessful cases are underreported. This would be an unfortunate state of affairs, because unsuccessful interventions may be the ones we

[15] If a modelling project was reported in more than one publication, the information from all publications found was combined. Similarly if a publication was a multiple case description, cases were split into single entries in the database. One study that employed an experimental design was coded as a single entry, as data were aggregated for all cases involved.

can learn most from. On the other hand it must be pointed out that the overall positive character of cases is not surprising, since the group modelling interventions employed here have been developed in a design – test – redesign fashion in a number of iterations. Early publications (e.g. Randers, 1977) report on problems on the basis of which future interventions were adapted. Eden (1992a: 10) describes this process as follows:

> *'Each of the proponents are proponents because they believe their system meets the theoretical and practical requirements they have set themselves – if they did not promulgate their own systems then the systems would be different!'*

In short the extent to which systematic biases exist is not known, and we thus have to be careful when drawing conclusions. On the other hand 107 case descriptions were identified, which gives us the opportunity to try to go beyond the insights generated in the single case descriptions, as a first step towards arriving at more general conclusions on group model building effectiveness.

The data that were gathered on each modelling project and recorded in a database, can be ordered in five general categories:

1. background characteristics;
2. organisational characteristics;
3. problem to be modelled;
4. characteristics of the intervention;
5. assessment of modelling impacts.

Background characteristics of each publication that were recorded are the authors, title, source (journal or proceedings) and date of publication. The first empirical study into the effects of client involvement in system dynamics modelling dates back to 1961. From the literature review it appears that only three other cases were published before 1970. In the 1970s, a total of four cases appeared, growing to 16 in the 1980s. From 1990 to 1999 between three and 13 cases appeared in print each year, indicating a fast growth in publications on group model building.

With regard to organisation, the following characteristics were stored: sort (profit, non-profit or governmental), sector (e.g. energy or financial services), name and size of the client organisation, and name of the consultant organisation.

Problem elements that were deemed important are motive (for starting the intervention), the research question(s) on which the modelling effort focused and its type (i.e. exploratory, descriptive, explanatory, or prescriptive), the importance of the problem modelled as judged by participants, and whether or not implementation of results was expected from the outset of the project.[16]

[16] The types of research questions are borrowed from a typology of fundamental and applied research (Swanborn, 1987). An open question aimed at uncovering elements related to the subject of the study,

The following aspects of the intervention itself were coded. First, the database contains a more or less open description of the different techniques employed for building the model. The model itself was characterised as qualitative or quantitative, by size, whether a preliminary model was used or not, which phases were followed and in what phases the client actually participated. In addition, the number and function of participants involved were recorded. Finally, the database contains the sources of information for building the model (apart from persons or groups, these could be documents, real life situations, or models - system dynamics or otherwise), the software used, other materials, and the total time span of the intervention.

The most elaborate category in the database is the evaluation of modelling results. Both the research design of the evaluation (i.e. experiment, survey, case study) and the data collection methods (i.e. individual/group interviews, content analysis, questionnaires, observations) were recorded.[17] It is important to note that reports are mostly of a qualitative nature. Studies employing questionnaires or other means of quantifying outcome results are rare. We also recorded a. subjects (number and function of persons involved in the evaluation); b. the researchers leading the evaluation; as well as c. the time span covered. Record was also kept of the way in which the client received feedback on the results of the modelling project (e.g. written report, oral presentation).

The final entry describes the outcome variables that were reported. Here quotations from the original text were used as much as possible. The quotes from the original text were summarised by using the keywords in the following table. The keywords in the table are used as a representation of the most important results of group model building as included in table 2.6 in the previous chapter.

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was marked as 'exploratory'. If the aim was to identify facts or delineate a state of affairs, the modelling question was categorised as 'descriptive'. If the model was used to identify the causes or reasons for a situation or development, it was termed 'explanatory'. A 'prescriptive' focus was one in which a concrete action to bring about change was intended.

[17] The designs are (Swanborn, 1987; Cook and Campbell, 1979):

- an experiment, using pretests and posttests, a control group and random assignment of individual subjects to the experimental or control group;
- a field experiment, using pretests and posttests, a control group but no randomisation;
- a one-group pretest-posttest, identical to the above but without a control group;
- a survey, involving only a posttest;
- a case study, if the description of the modelling process is focused on the project and its setting.

| | |
|---|---|
| *Individual* | [positive reaction] or [negative reaction]: personal evaluations of the intervention or model (e.g. ownership, discomfort, trust)<br>[insight] or [no insight]: learning<br>[commitment] or [no commitment]: a decision or commitment to results<br>[behaviour] or [no behaviour]: changes in individual behaviour or implementation of conclusions |
| *Group* | [communication] or [no communication]: exchange of viewpoints<br>[consensus] or [no consensus]: a shared view of the problem or actions<br>[common language] or [no common language]: understanding of other participants |
| *Organisation* | [system changes] or [no system changes]: organisational or physical changes (e.g. production lines, personnel policies)<br>[positive results] or [negative results]: results of system changes (e.g. for profit or morale) |
| *Method* | [further use] or [no further use]: further use of system dynamics methods<br>[efficiency] or [no efficiency]: intervention elements or contextual factors that fostered or hampered the effectiveness of the intervention |

*Table 3.1 Keywords used for scoring the outcomes of group model building cases*

An entry was made in the categories above only when authors reported on this aspect. If e.g. nothing is said about insight, this category is left open. In other words [no insight] is only recorded if the author explicitly states that no learning has occurred. The decision to use a dichotomised score follows from the general nature of the studies collected. A large number of studies revert to rich descriptions of the phases and conclusions reached in the modelling process. Only a small subset use quantitative measures of results such as Likert-type questionnaires. If available, these quantitative results were recorded separately after each keyword. In the analysis of results, qualitative and quantitative results will be contrasted.

The following coding procedure was used to determine the entries in the database. First, one author read a complete publication and entered his conclusions in the relevant fields described above. Second, 36 publications were reread by another author and entries were checked. A comparison of the entries of different authors revealed few differences. Background and organisational characteristics were scored almost completely similar by all authors. The scores on problem type and intervention characteristics showed the most differences. Since these are the most general entries in the database, this is not surprising. Authors turned out to have different definitions of scores on 'implementation expected', but after discussion a common definition was agreed on and cases were scored in a similar fashion. With regard to the most important category in the database, the evaluation of modelling results, few differences with the original entry were found. Differences were again

discussed, and after referring to the original source (the published case report) a unanimous decision on all scores could be reached.
In the following section, context (client and problem characteristics), mechanism and outcome elements are described separately. Section 3.6 addresses the question whether particular combinations of context, mechanism and outcome variables can be identified from the database. This is in line with Pawson and Tilley's (1993) statements that the contribution of research is to provide further detail on which intervention yields which results in which circumstances.

### 3.3 Context elements

This section addresses the most important contextual elements in group model building interventions. In section 2.6 two important contextual elements were identified: the problem addressed and the client. Problem characteristics are described first. The type of problem to which group model building is most often applied was described in section 2.4 as a complex problem. Modelling is most often used in so-called messy problems, which are both socially and analytically complex. From the descriptive studies it appears that group model building is sometimes used in less urgent problems as well. Problems which are not perceived as particularly important by participants, are mostly modelled in a training or demo exercise and in most cases there is no expectation of implementation of results. These projects are either initiated by champions working within an organisation (who have recently come into contact with system dynamics tools) or by internal consultants suggesting these as tools for continuous improvement. One case started out as quite urgent, addressing a matter of considerable importance to the client organisation, but became less urgent as a more serious matter (a merger) developed in another place in the client organisation (Verburgh, 1994).
A modelling project was listed as prescriptive if its purpose from the outset was to identify actions to steer model behaviour in the preferred direction. There is a subset of group modelling cases that are focused on implementation, but are not expected to come up with concrete actions to alleviate the problem. These projects:

- are aimed at discovering relevant changes in the organisational environment (scenario-studies by Genta, Kreutzer, Anderson, Hinote, Hood and McMillan, 1994; Morecroft and Van der Heijden, 1992);
- explore policy impacts (Rohrbaugh et al., 1997; Akkermans, 1995, case banking; Royston et al., 1999; Delauzun and Mollona, 1999, Morecroft, Lane and Viita, 1991; Covert-Weiss, Clark and Odence, 1998);
- are intended as a pilot for assessing the fit of the method to a specific problem field (Cavana et al., 1999).

As can be expected, all projects aim to explain situations or developments over time. System dynamics is sometimes credited for its free format, in which models are usually started with a 'blank paper' instead of pre-fixed notions on elements that have to be included (Coyle, 1998). However, only five studies can be said to have an explicit exploratory orientation from the outset. Most studies depart from specific hypotheses on the causes of problematic behaviour, and add additional structure when needed.

With regard to the client it can be concluded that modelling is used in a wide variety of organisational settings. About 60 percent of all group modelling studies were conducted in profit organisations, 20 percent in non-profit settings, and 17 percent in governmental institutions. The size of client companies ranges from a few employees to (divisions of) large multinationals with revenues in the 100s of millions of dollars. The following table gives more detail on the organisations where the interventions took place.

| *sort* | | *field* | |
|---|---|---|---|
| profit | 65 | production | 37 |
| | | (oil 14 ; electronics 5; chemical 4; transport and vehicles 5; other 9) | |
| | | services | 25 |
| | | (insurance 9; software 7, finance 3; other 6) | |
| | | distribution | 3 |
| non-profit | 21 | university | 7 |
| | | secondary school | 2 |
| | | energy | 3 |
| | | defence research | 3 |
| | | other research | 3 |
| | | K-12 | 1 |
| | | charity | 1 |
| | | broadcasting | 1 |
| governmental | 18 | national | 9 |
| | | (healthcare 1, transport 4, defence 2, development issues 1, forestry 1) | |
| | | state | 6 |
| | | county | 2 |
| | | city | 1 |
| mixed | 3 | inter-organisational co-operations | 3 |

*Table 3.2 Background of client organisations*

At a more specific level, client characteristics also refer to the individual participants in the sessions. Generally participants are line managers. Members of staff or other experts participate in some projects, and a minority of projects is done with students.

## 3.4 Mechanism

### 3.4.1 Introduction and general description

This section describes the intervention elements reported in the case studies. In the last chapter four important elements were identified:

- modelling phases in which the client was directly involved;
- type of model used :qualitative or quantitative;
- whether or not a generic model was used;
- the size of model built in the intervention.

Each of these is addressed in the following. The purpose of the description of intervention elements in this section, is first to provide an overview of techniques and steps followed in modelling. This adds to the prescriptive description of group model building approaches in section 2.3.6. The second purpose of looking at intervention elements in more depth, is to clarify how the intervention affects participants. In section 2.6 the mechanism through which group model building changes participants was described at a very general level: facilitation and modelling. By identifying specific elements we might be able to state more clearly *why* group model building is effective.

Before turning to the specific elements, the general character of group model building projects is described by looking at the number of participants and their time involvement in a project. The number of participants involved in face-to-face interaction is mostly between five and 12, and seldom larger than around 20. If more people are involved, most work is done in subgroups that meet at regular intervals to present findings to each other. In some cases groups as large as 30 to 160 participants work in subgroups using tools such as hexagon brainstorming, GroupSystems, or management flight simulators.

The time between start of the project and handover of final results varies from two days to five years. Of the 66 studies providing detail on duration, about one half is completed within three months, and two out of three in six months. Most projects take the form of two to four workshops, with intermediate feedback and reports, e.g. in the form of a workbook. Workshops may be an intensive full-day meeting, or consist of two to three hours of model building. The hours the client is involved in building the model is specified in only a few studies. Time investment seems to vary between 12 and 25 hours. An exception is the study by Hines and Johnson (1994) who involve participants in 12 full-day sessions over 12 weeks.

### 3.4.2 Phase of involvement

The first dimension on which group model building approaches differed, was the phase of modelling in which participants are involved. The modelling phases described in section 2.3.4 progress from the identification of the problem, through conceptualisation and several quantitative phases (formalization and sensitivity analysis) to estimation of model validity and policy experimentation to the final stage of implementation. The empirical studies gathered here clearly show that an abundance of techniques is used to involve participants in each of these stages. In building a model, participants perform three types of cognitive tasks (Vennix et al., 1992): elicitation of information, exploring courses of action or convergent tasks, and evaluation. From the modelling studies it appears that the elicitation phase is supported by using individual techniques such as interviews, cognitive mapping, nominal group technique, or workbooks. Alternatively, elicitation of information is done in small subgroups (Andersen and Richardson, 1997). When it comes to convergent tasks, participants are asked to choose between alternative problem formulations, model structures, or policy options. These require the input and confrontation of opinions of the group of participants as a whole (Andersen and Richardson, 1997; Vennix, 1996). This phase mostly takes the form of a face-to-face discussion, although the Delphi method (Vennix et al., 1990; Hendrikx, 1998) and GroupSystems (Rouwette, Vennix and Thijssen, 2000) are also used. The evaluation phase also requires the group as a whole to discuss and agree on issues, although individuals and subgroups are used to prioritise issues (Andersen and Richardson, 1997).

A special case here is the involvement of participants in the quantitative stages of model construction. The literature offers few guidelines for the involvement of the client in the quantitative part of modelling (Mooij et al., 2001). Morecroft (1992: 13) proposes to use 'friendly algebra' and Ford and Sterman (1998) use a stepwise approach to have experts estimate graph functions (see also Andersen and Richardson, 1997; Richmond, 1987; 1997).

Of a total of 85 quantitative model building projects, 69 focus on implementable conclusions; 56 of these explicitly mention client involvement in the formalisation phase. In three projects the formal model is discussed with the client. Participants in 12 studies contributed to the formalization phase by estimation of parameters, sketching variables over time, or other forms of data gathering. In a small number of cases, members of the client organisation possessed modelling expertise themselves and in effect built the complete model.

In addition to the client, other information sources such as documents and observation of real life situations are used in a couple of cases.

### 3.4.3 Qualitative or quantitative model

The second intervention element is the use of qualitative or quantitative models. In section 2.3.3 on system dynamics assumptions and again in section 2.3.6 on group model building approaches, the discussion on the necessity of quantification was addressed. It appears that certainly not all system dynamicists feel that quantification is always necessary. From the studies gathered here, 85 use a fully quantified model, while in 22 studies (21 percent) a qualitative model is built.

### 3.4.4 Generic model

The third intervention element is the use of a generic model, that captures the essential characteristics of a specific class of problems (see section 2.3.6). The elicitation of participants' knowledge might be started after the problem to be addressed is agreed upon, but can also consist of discussing and adaptation of a preliminary model. This pre-made model can be qualitative (e.g. an archetype in causal loop format) or quantitative, ranging from several variables and loops to a model of substantial size (e.g. Verburgh, 1994). In the latter case, the group modelling part is limited to commenting on an already existing structure, and the difference with using a management flight simulator becomes small. In about one quarter or 23 of the studies gathered here, a preliminary model was used. In 20 studies the preliminary model was quantitative, in three instances qualitative.

### 3.4.5 Size of model

The final dimension along which group model building approaches differ, is the size of the model constructed. There is some discussion in the literature about the appropriate lower and upper bounds on the size of system dynamics models. Senge (1987: 875) discusses the benefits of very simple formal models 'involving only one stock variable and virtually no significant feedback loops' in the direct interaction with clients. Lyneis (1999: 45) feels that a model 'would probably need a minimum of several feedback loops and 20-30 equations' but also states that small Pugh-Roberts models contain 200-400 equations. He assumes that the appropriate size partly depends on the experience of the modelling team. With more experience, insight can be gained from large models more quickly. In addition, the different lower bounds mentioned by different authors might be due to the fact that Senge refers to models used in direct interaction with clients, while Lyneis seems to discuss the use of models for giving insight to a (more or less) experienced modelling team. An indicator for the size of models is the number of variables or equations. As an upper bound, Morecroft (1985: 16) suggests 100-200 equations and Hines and Johnson

(1994) 200-400 equations[18]. From the database it becomes clear that the size of models built, falls somewhere between an upper range of several thousand (two models), and a lower range of 5 to 19 variables (six models). Most models are either 20 to 49 variables (23) or 50 to 199 (18). Another 10 models are anywhere between 200 to 1000 variables.

## 3.5 Outcomes

### 3.5.1 Introduction and measurement

In this section, the results of the studies collected in the database are compared. I will group results into the categories depicted in table 3.3. In assessing the value of these evaluation studies, two considerations are important. First, the authors of most of these studies did not set out to assess their modelling projects on all aspects contained in this review. Authors might not report certain outcomes because they are deemed of less importance, e.g. positive or negative reactions of clients.

Second, the limitations of the data have been discussed earlier but need to be emphasised again. Most projects (88 out of the 107) can be described as case studies, which establish results at the individual and group level in a qualitative manner. All of the case studies use observation for data collection, six studies include individual assessment interviews and two use a group interview. Only 19 studies use a quantitative estimation of results (see table 3.3), either through a post test survey (14 studies) or through questionnaires employed at two points in time (five studies). In a post test survey participants are asked to indicate their level of learning, resulting in a subjective estimation. Measurement at two points in time allows for an objective estimation of changes in e.g. insight and consensus. Three objective studies employ a pretest-posttest one group design (Akkermans and Van Schaik, 1998; Kelly, 1998; Verburgh, 1994). Huz (1999) and Knops (2000) use a field experiment.

[18] The main indicator of model size of is the number of variables contained in the model. As each variable is defined by one equation, the number of equations and variables is equal and both terms will be used interchangeably.

| | |
|---|---|
| Akkermans (1995, case software services a) | Insight; Commitment; Communication; consensus; *No system changes* |
| Akkermans and Van Schaik (1998) | Insight; No consensus |
| Bentham and De Visscher (1994) | Positive reaction; Insight; Behaviour; Consensus; *System changes; Results; Further use* |
| Berkvens and Neomagus (1997) | Insight; Commitment; Communication; Consensus; Efficiency |
| Cavaleri and Sterman (1997) | Insight; Behaviour; System changes |
| Draper and Swanson (1990) | Reaction; Insight; Commitment; Efficiency |
| Hendrikx (1998) | Insight; Commitment; Communication; Consensus; Efficiency |
| Huz (1999) | Positive reaction; Insight; Behaviour; Communication; Consensus<br>System changes; Results |
| Kelly (1998) | Reaction; Insight; Communication; Consensus; Efficiency |
| Knops (2000) | Reaction; Insight; Commitment; Behaviour; Communication; Consensus; Shared language; Efficiency |
| Rouwette, Vennix and Thijssen (2000) | Positive reaction; Insight; Commitment; Communication; Consensus; Efficiency |
| Sancar (1987, case Door County) | Positive reaction; Insight; Commitment; *No behaviour;* Communication; Consensus; *Efficiency* |
| Sancar (1987, case Janesville) | Positive reaction; Insight; Commitment; Communication; Consensus |
| Vennix (1995) | Insight; Commitment; *Behaviour;* Communication; Consensus; *System changes;* Efficiency |
| Vennix, Gubbels, Post and Poppen (1990) | Insight |
| Vennix, Scheper, Willems (1993, case Nostradamus) | Insight; Commitment; Communication; Consensus; Efficiency |
| Vennix, Scheper, Willems (1993, case Dutch river system) | Insight; Commitment; Communication; Consensus; Efficiency |
| Verburgh (1994) | Insight; No consensus; Efficiency |
| Wallace and Sancar (1988) | Positive reaction; Insight; Commitment |

*Table 3.3 Studies employing quantitative assessments (concepts in italics measured qualitatively)*

Before describing results it is necessary to determine to which extent claims about effects of group model building can be considered accurate estimations of results. For example Weil (1980) and Doyle (1997) warn against the biases introduced by specific evaluation procedures. A useful way of identifying possible biases is to look at differences between formal quantitative assessments using questionnaires, and qualitative assessments employed in case studies. If different research methods arrive at different conclusions, this may be caused by inconsistencies between operationalisation or measurement of concepts. These inconsistencies should be identified and studied in more detail in order to arrive at valid measurements. Still, these results should not be interpreted as more than an indication, and any statement on recurrent outcomes of modelling should be based on more in-depth studies using more elaborate designs.

*Comparison of questionnaires and case studies*

The following table depicts the positive outcomes of the 107 modelling projects for three situations: overall (all studies) and by type of measurement (interviews/ observations and questionnaires). For each of these three situations, the second column contains the frequency of studies reporting positively on the outcome.

| Outcomes | All studies (n=107) | | Interviews/ observations (n=88) | | Questionnaires (n=19) | | Difference | |
|---|---|---|---|---|---|---|---|---|
| | *total* | *positive* | *total* | *positive* | *total* | *positive* | *phi* | *sign* |
| Positive reaction | 29 | 29 (1.00) | 19 | 19 (1.00) | 10 | 10 (1.00) | *const* | |
| Mental model refinement | 101 | 96 (.95) | 82 | 78 (.95) | 19 | 18 (.95) | .007 | .944 |
| Commitment | 35 | 31 (.89) | 23 | 19 (.83) | 12 | 12 (1.00) | .259 | .125 |
| Behavioural changes | 30 | 29 (.97) | 26 | 25 (.96) | 4 | 4 (1.00) | .073 | .690 |
| Communication | 41 | 40 (.98) | 29 | 28 (.97) | 12 | 12 (1.00) | .102 | .515 |
| Consensus | 53 | 49 (.92) | 38 | 36 (.95) | 15 | 13 (.87) | .138 | .316 |
| Common language | 13 | 11 (.85) | 12 | 10 (.83) | 1 | 1 (1.00) | .123 | .657 |
| System changes | 46 | 42 (.91) | 44 | 40 (.91) | 2 | 2 (1.00) | .066 | .655 |
| System results | 24 | 24 (1.00) | 23 | 23 (1.00) | 1 | 1 (1.00) | *const* | |
| Further use method | 41 | 41 (1.00) | 39 | 39 (1.00) | 2 | 2 (1.00) | *const* | |
| Efficiency | 34 | 32 (.94) | 24 | 22 (.92) | 10 | 10 (1.00) | .161 | .347 |

*Table 3.4 Assessment of group model building results in total and by measurement method (figures in brackets indicate the fraction of positive outcomes of* measurements *in that category). Phi coefficients for reaction and results are uncomputable as they are constants*

What is striking in the table above, is the low number of quantitative measurements (using questionnaires) of behaviour, common language, system changes and results. Even the 19 studies employing questionnaires for most outcome variables, almost invariably measure these concepts using observation, interviews or archival data, resulting in qualitative scores. However, the quantitative measures that are employed are based on subjective self-assessment questionnaires that are not specific to a particular problem and can be used in other situations as well. Assessment of behaviour changes, the use of more common language, system changes and results might benefit from a wider use of these questionnaires.

Before turning to the differences between measurement types, I will take a look at overall outcomes of all studies in the second and third columns. The total measurements indicate that the proportion of positive outcomes is quite high, from .85 for common language, to 1.00 for reaction and results (third column). Looking at the total group of studies, significantly more positive than negative results are found for all outcome variables (using a nonparametric binomial test with test proportion .50). Because of the small number of measurements I used a significance threshold of .01. For common language significance is .022 (exact, 2-tailed), for all other variables significances are lower than .000. With the exception of use of common language, I interpret this outcome as support for the positive effect of group model building on the outcomes in table 3.4.

The difference between questionnaires and interviews/ observations is small compared to the number of studies in each category. The difference percentage varies from 0 (reaction and results) to 17 (commitment). If the studies are regarded as a representative sample of a larger population of group model building studies, the statistical significance of these differences can be assessed. (The assumption that the collection method did not lead to systematic biases is discussed earlier). For assessing the dependence of outcomes on measurement type I used the phi coefficient, which in a two by two table is equivalent to Cramer's V. A phi coefficient close to zero should be interpreted as support for the expectation that outcomes do not depend on measurement type. A phi coefficient of .25 can be interpreted as a weak association (Nijdam and Van Buuren, 1994: 125). For positive reaction, mental model refinement, behavioural changes, system changes, system results, further use of method and efficiency, outcomes do not seem to depend on measurement type. For commitment, consensus, communication and common language the coefficients indicate a (very) weak dependence on measurement type. For common language only one quantitative assessment is included in the database, so I will not take this difference into consideration in the discussion of results.

The results strengthen the confidence that for reaction, mental model refinement, behavioural changes, system changes and system results, outcomes do not depend on measurement type. In the following each outcome is looked at in more depth.

### 3.5.2 Positive reaction

As is shown in table 3.4, in only about one quarter of studies (i.e. 29) can a statement on reactions be found. Statements such as improvement of work climate, more interesting work, belief in or acceptance of modelling results, enthusiasm, satisfaction or credibility are all coded as positive reactions. All reactions to the group model building interventions are positive.

### 3.5.3 Mental model refinement

A total of 101 out of 107 cases report on insight into the problem gained during modelling. In 96 cases the result is positive, indicating that group model building resulted in an increase in insight. In five cases no insight was gained. Two of the five cases in which no insight resulted are projects in which models are built with students. In one case, the aggregation level of the model did not correspond with the mental models of students, the model was too abstract (Ginsberg and Morecroft, 1995). In the modelling course facilitated by Rouwette, Vennix and Thijssen (2000), participants gained only moderate insight into the problem, and no insight in each other's assumptions. This is explained by the focus on document analysis for data gathering and the lack of discussion between students about the problem. In the three cases in which models on real life problems did not lead to insight, the model was too big to understand (Fey, 1978) or the issue was politically sensitive and too broad to achieve focus (Akkermans, 1995 case software services b). Cavana et al. (1999) report on a study in which two subgroups modelled drivers of health sector developments in New Zealand. The majority of the participants, clinicians and an environmental scientist, conclude not to have gained insight from the resulting abstract model. Broadly stated, these five studies share a mismatch between the level of abstraction of the system dynamics model and the clients' mental models, and the modelling techniques used do not match the project's circumstances (unstructured discussion on a political sensitive issue, individual data collection hampering learning about others' opinions).

In conclusion, if the level of abstraction is adequate and techniques are matched to the objectives of the study, group model building studies generally result in increases in insight. On the basis of the data gathered, the amount of increase is difficult to determine. The issue is further confused by the difficulty of establishing what counts as a 'large' or 'sufficient' increase in insight. In cases aimed at finding implementable solutions the increase in insight is probably best considered in relation to behavioural and systemic changes: if the clients succeeded in finding a solution to their problem, the insight gained can be assumed to be adequate and sufficient. This is further discussed under system changes.

### 3.5.4 Commitment

In only 35 cases an influence on commitment is reported. In the majority of these cases (31) commitment to the results of the modelling effort is created (These include all 12 cases in which commitment is measured in a quantitative way). In four instances clients indicate that they do not feel committed to the study's outcomes. Among the studies where authors report that the project did not lead to commitment, the political issue is found again (Akkermans, 1995 case software services b). In two other cases, management agreed on the analysis of the problem, but decided not to back up conclusions nevertheless (Watts and Wolstenholme, 1990; Raynolds and Raynolds, 1992). In the study by Campbell and McGrath (1999 case CSC problem) their direct client is reluctant to compose a formal report and present the recommendations to management.

At first sight, it may seem disappointing that only 35 out of 107 cases report on commitment. However, this may be due in part to the different interpretations of commitment. In one sense, commitment is taken to be the intention to implement results or changes in behaviour. Statements such as 'the client agreed on implementing result X' fall under this category of commitment. We then have to take into consideration that only 84 studies focus on results, which can be implemented from the start of the project. In 18 cases models are built for training or educational purposes, in which no implementation of conclusions is expected. In addition, even if clients in the modelling process are managers working on their own problem, the conclusion of the project does not necessarily imply a change in behaviour. The conclusions of the modelling process might indicate that no changes in management practices are needed, or that adaptations on other ('systemic') levels of the organisation are necessary. Also, some of the reports are completed immediately after the project, which might be too early to reach conclusions about implementation.

In summary, there are a low number of measurements of commitment that are generally positive, but this might be said to rest on different interpretations of the concept. From the 35 studies reporting on commitment, 31 state a positive effect on commitment. It thus seems that in general group modelling may have a positive effect on commitment, but the exact definition of the concept should be clarified in the future.

### 3.5.5 Behavioural changes[19]

For behavioural changes, results are comparable to commitment. A total of 30 studies report on this topic. In 29 studies projects are followed by changes in behaviour, and in one instance modellers report not to have affected behaviour. In this last study (Sancar, 1987 case Door County) participants in general agree to the statement 'the diagrams imply solutions', but the management (who did not participate fully in building the model) does not implement conclusions because, according to them, the model did not include all relevant aspects.

In conclusion, 29 out of 84 projects aiming at implementable solutions result in behavioural change. Although only in few projects clients state that they are not committed to results or do not rush to implement conclusions, the effect of group model building on individual behaviour seems to be surprisingly small. Possible reasons for the gap between the number of studies focused at implementation and the reports containing behavioural changes are similar to those mentioned in the previous section: results at other organisational levels might be aimed for. In addition, a number of reports are written immediately after the project or while this is still in its concluding phase, which might be too soon after the project for assessing any behavioural changes.

### 3.5.6 Communication quality

Frequently system dynamics is considered as a tool to improve communication in a team. The results for communication are as follows: 41 out of 107 cases report an influence on communication, 40 of which indicate an increase in the quality of communication. In one instance quality of communication is reported not to have increased (Akkermans, 1995 case software services b). There is a weak dependence of outcomes on measurement type, but most striking about this result is the low number of reports on communication, and the overall positive outcome.

In this case the low number of reports cannot be explained by measurement on the short term. Applying a method such as model building must affect communication immediately, which makes it unlikely that an assessment study fails to note its impact because it is limited to short-term outcomes. A possible explanation for the low number of reports is that in applying a new tool for decision making, changes in communication are unavoidable and therefore are not detailed, in order to avoid 'stating the obvious'. The fact that in 19 cases consensus does result, although nothing is being reported on communication, points in the same direction. After all, exchange

[19] In section 2.5.1 on group model building goals, behavioural change was interpreted as the equivalent of implementation (of system changes) on the individual level. As can be seen from the table, both concepts are not identical. Changes on the level of the system, e.g. in personnel policy, do not have to imply behavioural change for participants in the modelling sessions, and vice versa.

of viewpoints or communication is a necessary condition for consensus to emerge (Scheper, 1991).
Although the number of cases, which report on quality of communication is low, it seems that in general group model building leads to an increase in the quality of communication between participants.

### 3.5.7 Consensus

Consensus or alignment of problem visions is often considered a prerequisite for shared action (Huz, 1999). In 53 out of 107 studies an influence on consensus is reported. In 49 cases a consensus view has been created, but in four instances clients indicate that there is no consensus on the conclusions of the modelling project. Two of the studies reporting no consensus have been discussed before (Akkermans, 1995 case software services b; Ginsberg and Morecroft, 1995). Verburgh's (1994) objective assessment of mental model alignment shows no significant increase between pretest and posttest. Akkermans and Van Schaik (1998) find an increase in subjective self-assessments of consensus, but a decrease in objective consensus (i.e. an increase in the variance of problem elements). This again presents a picture of a limited number of reports of an overall positive character.
The studies gathered here seem to indicate the lack of a clear definition of consensus, which is again supported by the differences found between measurement types. Consensus could refer to agreement on a problem definition, the actions for alleviating the problem, or both. If the first definition is used, agreement on a model representing the problem would already constitute consensus. If consensus on actions is referred to, the concept is close to commitment. In addition, the concept of consensus implies 'complete agreement' for some, while for others an increase in convergence of ideas denotes 'consensus' as well (Scheper, 1991). As mentioned before, one study using an objective assessment of mental model alignment shows no significant effect (Verburgh, 1994). Huz et al. (1997) report more alignment in perceptions of systems goals, but no significant increase in perceptions of strategies for change.
In conclusion, the studies collected provide some support for the influence of group model building on consensus (in only four out of 53 reports the result is negative). A more careful consideration of the exact definition used, especially the difference between consensus on problem analysis and consensus on actions, might enable a more accurate assessment of the effect on consensus.

### 3.5.8 Common language

In many cases persons from different departments in a large organisation, e.g. finance or research and development, can be said to use different languages to

describe organisational problems. An effect on common language is reported in only a minority of studies: 13 out of the total of 107 studies. In 11 cases this effect is positive, and in two cases it is explicitly mentioned that no common language resulted. One of the two cases in which no common language is reported, is the political sensitive issue described by Akkermans (1995 case software services b). The other case (Zazara and Fisher, 1996) reports on the development of cross-curricular models with teachers of pre-college students. After three weeks of training, 70% of teachers uses modelling in their classes, but all of them use models specific to their own discipline. The interdisciplinary models were not used.
The low number of reports and the low significance of results make it impossible to draw conclusions. In the system dynamics literature, the expectation can be found that system dynamics serves as a uniform platform for communication that bridges differences between organisational departments (e.g. Richmond, 1987: 132). On the basis of the studies gathered here, this expectation can neither be confirmed nor disconfirmed.

### 3.5.9 System changes and system results

Of the 107 cases, only 46 report on system changes. Of these 46, 42 report implemented changes at the system level. In four cases modelling conclusions do not lead to changes at the system level. In two instances the model suggested changes in the reward system in the client organisation, which the management was not rushing to implement (Roberts, Abrams and Weil, 1978; Akkermans, 1995 case software services a). The third study is the political sensitive issue mentioned before (Akkermans, 1995 case software services b). In the study by Campbell and McGrath (1999 cases CSC problem), discussed under commitment, the direct client does not want to pass on the results of the modelling project to higher management. At total of 24 studies provide details on the results of system changes. All of these 24 studies report positive results.
These results should be compared with the number of studies that set out to find implementable solutions. A total of 84 projects were focused on implementation, which suggests that in half (42) of the relevant cases changes are implemented. More than half (24) of these changes led to positive results. As a considerable number of reports collected here is written immediately after the project, limiting measurement to short-term outcomes, this number might be a low estimate. The question of system changes connects to the issue on what constitutes a 'sufficient' increase in insight: in at least half of the relevant projects (those focused on implementation), learning about the problem took place to such an extent that new solutions were implemented.

### 3.5.10 Further use of modelling and efficiency

When it comes to further use of the method, in 41 out of 107 cases system dynamics modelling continues to be used after the initial project is over, which again suggests that group model building has an impact on client organisations.

In 34 out of 107 cases the efficiency of system dynamics modelling is considered. In 32 of these 34 cases, group model building is found to be more efficient than traditional methods used for tackling similar problems.

## 3.6 Context - mechanism - outcome configurations

### 3.6.1 Introduction

Pawson and Tilley (1993) urge us not to simply add projects together without trying to assess meaningful differences between studies. As discussed in the previous chapter, differences between contexts and mechanisms inevitably will lead to differences in outcomes. If e.g. an organisation is characterized by political struggles, the process of model construction will be affected if only because participants are less likely to exchange information openly. The combination of a highly political context and a model which contains only a subset of the available information is in turn less likely to lead to implementable results. Naturally, many different context - mechanism - outcome configurations could be created. A logical choice seems to be to use the mechanism elements as a starting point. Pawson and Tilley (1993) describe how practitioners shape their intervention to the needs of a specific situation, often in an implicit way. In effect they are using rough theories of how their intervention can be best tailored to the needs of particular participants or environments. Vennix (1996) for instance describes how a modelling project needs to be built around more structured techniques to accommodate a large group of participants.

In the previous chapter four mechanism elements were singled out as the most important: phase of involvement, the use of a qualitative or quantitative model, the use of a generic model and model size. On the basis of the database, the phase of involvement can not be consistently related to either context or outcome variables. In addition, the 23 studies that employed a generic model do not differ from other studies with regard to context or outcomes. The remaining two elements, qualitative or quantitative model and model size, do show specific patterns of context and outcome but only when used in combination. In order to identify configurations, qualitative models (see column 2 of table 3.5), small quantitative models (column 3) and large quantitative models (column 4) were compared. In order to arrive at valid conclusions on implementation, I chose to place modelling efforts not aimed at implementation in a separate category, i.e. demo/ training (column 1). A total of 82 studies provided enough data to be placed in one of these categories.

| **Context** | | | |
|---|---|---|---|
| *Demo/ training* | *Conflict/ intangible* | *Data-richt/ tangible* | |
| **Mechanism** | | | |
| 18 studies, diverse models<br>no implementation intended (students or experts)<br>approx. 4 participants<br>4 sessions of 2-3 hours each | 15 studies, qualitative models<br>average 7 participants<br>3-5 sessions of 3-8 hours each | 19 studies, small quantitative models<br>average 7 participants<br>5 sessions of 3-8 hours each, up to several months | 30 studies, large quantitative models<br>average 22 participants<br>about one year |
| **Outcome** | | | |
| mental model .88 (17)<br>commitment 1.00 (6)<br>behaviour 1.00 (1)<br>communication 1.00 (13)<br>consensus .83 (6)<br>system changes none<br>system results none | mental model .87 (15)<br>commitment .71 (7)<br>behaviour 1.00 (3)<br>communication .86 (7)<br>consensus .80 (10)<br>system changes .71 (7)<br>system results 1.00 (3) | mental model 1.00 (18)<br>commitment .83 (6)<br>behaviour 1.00 (6)<br>communication 1.00 (4)<br>consensus 1.00 (7)<br>system changes 1.00 (8)<br>system results 1.00 (3) | mental model .96 (26)<br>commitment 1.00 (5)<br>behaviour 1.00 (9)<br>communication 1.00 (4)<br>consensus .93 (14)<br>system changes .94 (18)<br>system results 1.00 (11) |

*Table 3.5 Context – mechanism – outcome configurations. Behind each result, the proportion of positive outcomes is given as a percentage of measurements of that outcome. Total number of measurements is indicated in between brackets*

In table 3.5 results are tabulated for the most important goals of group modelling only. Reactions or shared language will not be discussed in comparing results due to the low number of studies that included measurements on these outcomes. In addition I will concentrate on outcomes that are relevant to the problem addressed in the project, and disregard outcomes related to the method. In the previous chapter the most important goals of group model building were defined as the following: mental model refinement, fostering of communication quality, creation of consensus, system changes and system results. The table above includes commitment and behavioural change as additional variables on the individual level. In order to make a comparison between subgroups easier, the proportion of positive outcomes of measurements in each subgroup is indicated. For example, out of 18 demo/ training projects, 17 measure insight, of which 15 (.88) report a positive effect. In the following context, mechanism and outcome are looked at in turn.

### 3.6.2 Context

As stated the relevant studies for comparing the effects of different model types are the projects that focus on implementation in column 2, 3 and 4. These subgroups do not differ with regard to organisational background: sort, sector and size of client organisations are comparable. No difference can be found in problem importance either. In each subgroup a comparable number of studies (53 to 60 percent) is considered important by participants. Several authors feel the choice for qualitative versus quantitative models depends on problem characteristics such as scope, tangibility, data availability and conflict between stakeholders (Akkermans, 1995; Coyle, 2000). However, it is not very clear how these should be operationalised, as many problems entail soft, intangible factors and some degree of conflict. These problem characteristics seem to boil down to the extent to which stakeholders have information on the problem and are in dispute over the problem. In the research by Hickson et al. (1986) these factors form the analytical and social dimensions of problem complexity. Hickson et al. (1986) provide further detail on how to operationalise complexity. Several elements of complexity can be found in the data in this study, i.e. rarity or frequency with which similar matters occur, diffusion of consequences and interests involved. These factors are included in the database entry on motive for starting the intervention. These indicators show that qualitative models are more likely to be applied in situations that are new to the people involved, have widespread consequences and involve a broad range of interests. Quantitative models are more often applied to production, distribution or human resource problems that organisations are likely to have encountered in some form before, involve fewer parties and are more restricted in consequences. Basing ourselves on data on frequency, diffusion of consequences and interests involved, it seems that the decision whether or not to quantify does indeed depend on problem characteristics.

### 3.6.3 Mechanism

The general process of modelling in each of the subgroups can be described as follows[20]. In the first subgroup (demonstration models) participants are not expected to implement results. In these projects diverse models are constructed, of different

[20] There are a couple of projects that do not follow the general pattern with regard to number of participants or time investment. Educational projects usually involve a small group of participants and a limited time investment. Exceptions are Rouwette, Vennix and Thijssen. (2000), Knops (2000) Ginsberg and Morecroft (1995), who involve groups of 30, 32 and 70 students respectively. Vennix (1996), Guthrie (1998) and Eriksen and Nielsen (1985) take a much longer than average time investment. Qualitative models that in contrast to the general pattern involved a large group of participants are described by Genta et al. (1994, using scenarios) and Vennix et al. (1990, using Delphi).

sizes, qualitative as well as quantitative. The group of participants is on average small and usually the time investment is limited.

In the second subgroup qualitative models are used for finding implementable results. Models are made with a small group of managers in a limited span of time.

The cases in the third subgroup result in small quantitative models of a maximum of 50 equations. These models are built with the participation of a small group of managers. Time investment is limited, although five projects are measured in months. In most cases the quantitative modelling is not done in front of the group of participants, but rather by the consultants separately and then discussed with the clients.

The largest group model building projects are those in which models of 50 and more equations are built. The scope of these projects is large both with respect to number of participants and time investment. On average, building these models requires a client organisation's commitment for about one year and about 22 participants in model construction. In some cases a very large number of people is involved, e.g. the 'team of teams' which consists of 160 people (Graham and Walker, 1998). Not surprisingly, these projects also take the longest to complete.

### 3.6.4 Outcome[21]

The first subgroup, studies not aimed at implementation, again presents a special case. If commitment in any of these studies is created, this is commitment to the analysis made and not to the solutions found. In one study an impact on behaviour is found (Knops, 2000), when students have to vote for one of two proposed interventions in the problem. Here, casting a vote is the behaviour of interest and not the actual implementation of conclusions. When it comes to the two discussion points within the system dynamics community mentioned earlier, quantification and size of models, I will again only look at differences between subgroups of studies focused at implementation.

The only outcomes that differentiate between subgroups 2, 3 and 4 are commitment, consensus and system changes. Qualitative models are less likely to lead to commitment, consensus or system changes than (small or large) quantitative models. The likelihood of positive results of system changes is equal for both types of models. In addition, qualitative models do not differ substantially from quantitative models with respect to their capacity for generating insight, behavioural changes or communication.

[21] Please note that due to the low number of cases in each subgroup, a small change in outcomes found has a large proportional impact. I will therefore only consider a difference of percentages larger than 20.

These outcomes should be considered against the different contexts in which models are used. Qualitative modelling appears to be an intervention requiring relatively few organisational resources (time and participants), and is instrumental in clarifying intangible matters. Quantification adds substantial benefits in situations where the problem is more structured and justifies a larger investment in terms of participant time.

### 3.6.5 Conclusion context - mechanism - outcome configuration

In conclusion, section 3.6 looked at the difference between four elements of client involvement. These elements were identified in section 2.3.6 as the main dimensions along which group model building approaches differ. Two of these dimensions, the use of a qualitative or quantitative model and model size, can in combination be related to context and outcomes variables. Qualitative models are more likely to be used in messy problems than quantitative models (both small and large). In comparison to small and large quantitative models, qualitative models are less likely to lead to commitment, consensus or system changes, but since these models are applied in messy situations this is not surprising. Both types of models have a similar impact on mental model refinement, behavioural changes, communication and system results. On the basis of the studies gathered here, the main difference between small and large quantitative models seems to be the number of participants and average duration of projects. No large differences in outcomes between models of different sizes could be identified.

The purpose of looking at mechanism elements in more depth, and trying to relate these to the circumstances and outcomes of modelling, was to get a clearer idea of the way in which group model building achieves its goals. In other words, to partly open up the black box and see how participants are affected by the intervention. However, on the basis of the results found here it is difficult to draw conclusions about the mechanism operating in group model building. The configurations that were identified can be interpreted in multiple ways. One might argue that quantified models inspire more confidence because they allow for more testing and analysis of model behaviour, leading to more commitment, consensus and system changes. Alternatively, one might say that quantitative models are used in a less conflict-ridden situation, where commitment, consensus and system changes are more easily created. On the basis of the data it is difficult to decide between these alternative explanations. It seems clear that a conceptual framework is needed to arrive at an explanation of group model building effects.

## 3.7 Conclusion

This chapter reported on descriptive studies of group model building that describe applications to organisational problems. Effectiveness studies into system dynamics interventions have been published almost since the inception of the field. Many case studies show how clients were involved in model construction. There is also a growing tradition of research into microworlds (Andersen, Richardson and Vennix, 1997; Größler, 2000). However, some of the most fundamental intuitions about outcomes of system dynamics interventions, i.e. gains in insight and system performance, prove very difficult to test and conclusions about robust outcomes are difficult to draw. In this chapter qualitative and quantitative case reports of group model building applications were reviewed with three goals in mind: a. to provide an overview of descriptive studies; b. to identify robust outcomes of interventions; c. to identify meaningful patterns of interventions, contexts and outcomes. With regard to these goals, the following conclusions can be drawn.

First, group model building studies are reported across a wide variety of contexts. In a subset of cases modelling is used for demo or training purposes and not for 'real life problems'. Applications of group model building to actual organisational problems are reported in profit, non-profit and governmental organisations of different types and sectors. In this meta analysis, 107 reports could be catalogued that include descriptions on context, mechanism and more or less explicit assessment of outcomes.

The second conclusion refers to the outcomes reported in these descriptive studies. A number of differences in operationalisation and measurement of outcomes could be identified. With regard to the majority of outcomes, qualitative and quantitative assessment studies showed comparable results. In the following table the conclusions for each outcome element are listed.

| | | |
|---|---|---|
| Individual | Positive reaction<br>Mental model refinement<br>Commitment<br>Behavioural change | Robust positive effect<br>Robust positive effect<br>Defined differently, few measurements, generally positive<br>Defined differently, few measurements, generally positive |
| Group | Quality of communication<br>Consensus<br>Common language | In general positive effect<br>Defined differently, few measurements, generally positive<br>No conclusion, few measurements |
| Organisation | System changes<br>Results | In general positive effect<br>In general positive effect |
| Method | Further use<br>Efficiency | In general positive effect<br>In general positive effect |

*Table 3.6 Conclusions of descriptive studies of group model building per outcome*

Learning about the problem seems to be a robust outcome of group model building. A large number of studies points to refinement in mental models. Although it seems rather straightforward to expect modelling to lead to learning about a problem, research into microworlds frequently fails to find an effect (Andersen et al., 1997). The database shows that the majority of both case studies and quantitative assessments report learning effects. These measurements include subjective self reports as well as more objective pretest posttest comparisons. This seems to point to a real difference between participation in model construction and operating a finished model as in microworlds. The results here are in line with Sterman's assertion (1994: 320):

> *'To learn […] participants must become modelers, not merely players in a simulation. In practice, effective learning from models occurs best, and perhaps only, when the decision makers participate actively in the development of the model.'*

In general commitment and consensus are found to increase after participation in modelling, although research can benefit from careful definition and operationalisation of both concepts. Commitment and consensus are defined and operationalised in different ways. Definitions employed in questionnaires diverge from those in case studies. A limited number of studies reports on communication, in general positive. With regard to common language the low number of measurements does not allow a conclusion.

Fewer studies, although still a substantial number, report on behavioural changes, system changes and improvements. Half of the studies focused on finding implementable solutions result in changes in organisational policies. About half of these changes result in system improvements. The use of modelling is continued after the initial project is finished in a number of cases, and its efficiency is generally considered satisfactory.

The third conclusion refers to patterns of context, mechanism and outcomes. From the 107 cases discussed in this chapter, it appears that organisational background does not have an influence on the techniques used in the modelling sessions. Problem characteristics do have an influence on the approach chosen. Qualitative models are more likely to be used in problems of greater complexity than quantitative models. Second, apart from the use of quantification, the techniques used to involve participants in modelling differ on many other aspects as well. In section 2.3.6 four dimensions where found along which approaches differ: phase of involvement, the use of a qualitative or quantitative model, the use of a generic model and model size. Only the distinctions between small and large, and quantitative and qualitative models can be consistently related to context and outcome variables. Repeatedly system dynamicists express their appreciation for one type of model over another, i.e. quantitative versus qualitative (see the discussion by Coyle, 2000) and small versus large models (see Lyneis, 1999). In this analysis a number of differences between modelling projects focused on finding implementable conclusions were found, depending on the fact whether they employed qualitative models, small quantitative models or large quantitative models. With regard to the main goals of group model building, the following results were found:

- mental model refinement: no differences between the three types;
- quality of communication: no differences between the three types;
- consensus: small and large quantitative models score better than qualitative models;
- system changes and system results: small and large quantitative models have a higher impact on system changes; all three types are equally likely to lead to system results.

In addition, the three model types were compared with regard to commitment and behavioural changes. Qualitative models are less likely to lead to commitment than (small or large) quantitative models. With regard to behavioural changes, the three model types do not differ. In total, the only differences between (small and large) quantitative models and qualitative models is that the former are more likely to lead to commitment, consensus or system changes.

The purpose of this chapter was to identify relevant research questions for the empirical part of this study. Overviewing the results in this chapter, it is clear that evaluation of group model building could benefit from a more rigorous assessment of many outcomes. However, a more basic problem is that goals and mechanisms are largely unconnected. The descriptive research in this chapter, like the prescriptive studies in the foregoing chapter, does not contain many ideas on how particular elements of group model building contribute to its goals. The outcomes depicted in figure 2.5 can be found in the case studies reviewed here, but the cases do not provide more insight into the relations between goals and mechanisms. In the descriptive studies discussed in this chapter, the mechanism is not specified in more detail than in the general elements 'facilitation' and 'modelling'. It is for instance implicit that constructing a model changes a participant's mental model of the problem, but how and under which conditions is not specified. The intervention is mostly treated as a black box in which many different techniques are used, and the contribution of separate elements to the overall goals is unclear.

In addition, goals are largely considered in isolation. It is e.g. clear that insight can contribute to implementation, but how exactly remains implicit. The analysis of context – mechanism – outcome relations in this chapter is limited to a general level. It does not provide much detail on the mechanism through which group model building influences participants. Before formulating research hypotheses, it seems therefore worthwhile to identify a conceptual framework specifying the relations between the concepts above. This is the topic of the next chapter.

# Chapter 4 Conceptual framework

## 4.1 Introduction

This chapter discusses a theoretical framework of the way group model building affects a decision making group. Before research questions on the impact of an intervention can be formulated, it is necessary to have at least a basic idea of how intervention elements relate to outcome elements. A starting point for this is the identification of intervention goals on one hand, and the way practitioners try to accomplish these goals on the other. This has been partly described in the previous chapters, when addressing the different approaches to group model building and results reported in case studies and field research. Methodological papers, described in chapter two, frequently provide descriptions of the goals of group model building on a rather general level. The main outcomes were mental model refinement, fostering quality of communication, creation of consensus, implementation of system changes and system improvement. The mechanism through which group model building affects participants was also described on a general level, focusing on model construction and facilitation. The case descriptions reviewed in chapter three, provide rich accounts of specifics of a modelling project. These include amongst others how a particular insight persuaded a client to implement modelling results. However, the descriptive literature does not offer many insights into how different goals are interconnected, or how these are related to the intervention. In short, what is missing is a conceptual framework on elements and effects of group model building. This conclusion reflects McGrath and Hollingshead's (1994) suggestion for the field of GDSS: in order to find meaningful patterns in outcomes, we first need to identify potentially relevant variables in group decision support and relate these to one another in a general framework.

In section 4.2 the reasons for formulating an integrated framework are described in more detail. Firstly, outcomes are considered. The most important goal of system dynamics modelling is implementation of model results leading to system improvement. Psychological studies and work in the broader field of GDSS suggests that in order to explain implementation, other variables than communication, insight and consensus need to be taken into account. The goals generally considered in system dynamics focus on individual and cognitive variables. Evaluation and shared meaning have a separate impact on implementation and need to be considered in a general framework. Secondly, with regard to mechanism variables, negotiation (influence attempts) needs to be considered in addition to facilitation and model construction. The third and last focus is on context variables. The fact that group model building is used in complex organisational problems has a number of consequences for the participants in the project. A complex problem can be expected to be highly relevant to those involved, and to create an inadequate ability to process available information.

In section 4.3 the goals of group model building are reconsidered in the light of these additions. On the individual level, Ajzen's (1991) theory of the impact of attitudes on behaviour incorporates many of the variables discussed before.

In section 4.4. the mechanism variables are addressed. Modelling and facilitation are expected to contribute to an open exchange of information. Negotiation is identified as an important additional mechanism variable. Exchange of information, influence attempts and the impact on cognitive changes are described by theories of persuasion.

In section 4.5 contextual variables are addressed. Problem urgency and the ability to process relevant information are captured by persuasion theories as well.

Section 4.6 provides a summary and integration of the context, mechanism and outcome variables discussed in this chapter.

## 4.2 Reasons for developing an integrated framework

### 4.2.1 Introduction

In this section the arguments for developing an integrated framework of group model building elements and effects are put forward. Outcomes, mechanism and context of group modelling are addressed in turn. For each category, the elements considered by the system dynamics literature are contrasted with the broader GDSS literature and studies in related disciplines such as psychology. In this way it is shown that other elements in addition to those considered by system dynamicists need to be incorporated in an integrated framework.

### 4.2.2 Outcomes

In section 2.5 the intervention outcomes were described, of which four main goals were selected: a. implementation of system changes and results; b. refinement of mental models; c. consensus and alignment; d. communication and common language. Relations between goals found in the prescriptive literature were described in section 2.5.6. The descriptive studies of group model building applications provide details on how these goals relate to one another in specific cases, but do not discuss more general relations between goals (see section 3.7). In this section literature from related disciplines is used to consider the relations between goals of group modelling again, in order to determine a conceptual framework and arrive at relevant empirical questions.

A striking feature about the goals of modelling is that they bridge the individual, group and organisational level. In this study the focus is on the individual level for two reasons. First, the group model building methodology is founded on insights from individual and small group decision making (see e.g. Vennix, 1996). The organisational level is not discussed in any great detail and in the intervention the individual participants are the focus of attention. Second, the implementation of project conclusions can often be equated with changes in the behaviour of participants in group model building. An effort is made to involve managers that can influence the implementation of conclusions resulting from model construction. By being directly involved in building a model, an individual is expected to gain new insights leading to changes in his or her behaviour, i.e. (helping to) implement a course of action. In conclusion it seems that group model building's main focus is the individual participant, while the group process is steered in such a way that the likelihood of increasing insight is optimised.

If the main goals are considered at an individual level, it seems that system dynamicists assume that there is a relation between communication, cognition (in the form of mental models and consensus) and behaviour. Two points of criticism can be levelled against these assumed relations. First, cognitive variables are less important for shaping behaviour than affective or evaluative variables such as attitudes (Fiske and Linville, 1980; Eagly and Chaiken, 1993). Second, on the basis of the descriptive studies considered in the last chapter, it seems that there is no clear definition of consensus. In section 2.5.4, four different interpretations were identified and a definition needs to be chosen before the relation of consensus to other goals can be specified. Both points are considered in more detail below.

*Cognitive and affective variables*

A review of studies on knowledge representation (Fiske and Linville, 1980) shows that research in this field is primarily concerned with cognitive processing. In general cognitive constructs such as mental models and schemas are studied in relation to information processing, and few studies address social behaviour. The authors conclude that 'schemas have not been linked to interpersonal behaviour' (Fiske and Linville, 1980: 549). Although cognitive psychologists often make the assumption that all forms of schemas have behavioural consequences, research into the impact of schemas on behaviour is scarce. In contrast, the relation between evaluative mental structures and behaviour is one of the central topics in social psychology. The attitude is the central evaluative structure in many social psychological studies. The difference between the two fields is captured in the following quote (Eagly and Chaiken, 1993: 19):

> *'Because evaluative structures are very likely to be infused with affect and to energize and direct behaviour, this concentration of attitude researchers on evaluations may be*

*advantageous with respect to some kinds of predictions, especially those regarding behaviour. Cognitions not laden with good-versus-bad meaning are probably much less likely to elicit emotions or energize behaviour.'*

Researchers in the field of group decision support frequently consider evaluative structures in their studies. In conceptual frameworks on GDSS, two types of evaluations are included as outcomes: the attitude towards the decision and the attitude towards other group members (McGrath, 1984; Pinsonneault and Kraemer, 1989; 1990). The importance of the attitude towards the decision for actual implementation of the decision seems clear from the quote above. In conclusion, evaluation needs to be considered together with cognition if we want to explain implementation of modelling conclusions.

*Definition of consensus*

In section 2.5.4 the system dynamics literature on consensus and alignment was described. Four different interpretations of consensus were uncovered. The descriptive studies in the last chapter also pointed to different conceptualisations of consensus. The following four definitions could be found:

- shared understanding: overlap in cognitive concepts and types of relationships;
- alignment: agreement on means and ends;
- the individual representation of consensus: the subjective estimation of the consensus view;
- shared meaning: overlap in the meaning of concepts.

In order to select a definition for the remainder of this study, three issues are important. First, a clearer idea on the content of consensus allows us to choose between the first two definitions. Second, most authors define consensus on the inter-individual level, while the third definition refers to an individual representation. Third, the last definition is different from the first two in that consensus is taken to refer to similarity of meaning instead of similarity in the labels of concepts. These issues are addressed below.

First, it seems useful to define the content of consensus: whether agreement on the dynamic system, means or actions, or goals is referred to. This distinction resembles the three mental models defined by Richardson et al. (1994): the goals model, the means model and the means/ends (dynamic system) model. Since a system dynamics model mainly concerns the dynamic system and Huz (1999) relates agreement on means and goals to organised action, it seems that all three elements are necessary when speaking about a complete consensus.

Second, it is important to decide whether consensus refers to an overlap between individual views, or a separately stored collective model. Before this can be decided on, more information is needed on the relation of either construct to individual action. Discussion of this point will be postponed to the section on the conceptual model.

Third, we need to consider the nature of mental models in order to determine what consensus means. A concept in a mental model can either be regarded as a label or alternatively its meaning can be assessed (cf. Scheper, 1991). The description of group model building in section 2.3 shows that over the course of a modelling project, the meaning of a concept may change although its label stays the same. Consider for example the following. In a modelling project it routinely happens that a participant proposes to relate a new variable to other variables in the model and explains why he would want to change the model in this way. As described before, the model will only be changed if the other participants agree. Often this leads to a discussion on what a variable refers to and in most cases an agreement can be reached on its place in the model. The fact that participants discuss changes in the model in this way, makes it likely that variables refer to concepts in their mental models. In addition, the case studies in chapter three provide numerous examples of model results participants previously had not considered or found counterintuitive. Vennix (1995) describes a modelling project for the Dutch Ministry of Transport. At the start of the project, policy makers responsible for the Dutch ports failed to see the relevance of the size of the Dutch merchant fleet to their area of interest. However, over the course of the modelling sessions, this variable was related to e.g. influence in international organisations and nautical know-how. Eventually the size of the Dutch fleet, through its impact on several other variables, was found to have an impact on factors such as the size of Dutch ports. We can therefore assume that the meaning of the concept 'size of the Dutch merchant fleet' to representatives of the Dutch ports has changed. In this example the name of the concept remains the same, but its relation to other concepts has changed and thereby its meaning is altered. A definition of consensus as merely an overlap in the labels used would clearly fail to address this change in meaning. Thus the interpretation or meaning of a concept will need to be taken into consideration. A 'true' consensus would need to be based on a similar interpretation of concepts.

This section suggested two additions with regard to the goals of group model building: consideration of evaluation next to cognition, and a conceptualisation of consensus. In the following section mechanism elements are addressed.

### 4.2.3 Mechanism

Mechanism elements were described in section 2.3. System dynamics modelling and facilitation form the basis for group model building. Both aspects are expected to be related to the goals described earlier: communication, cognition (mental models and consensus) and behaviour. In order to identify the mechanism at work in group model building, I opened up the 'black box' by looking at more specific descriptions of approaches to group model building (section 2.3.6). The differences between these approaches were categorised in four dimensions: a. modelling phase in which the client is involved; b. use of a qualitative or quantitative model; c. use of a generic model; d. model size. In chapter three on the case reports of modelling projects, differences between these categories were addressed. The modelling phase in which a client was involved was not easily combined with either outcomes or context. With regard to the use of a generic model the same conclusion applied. The two other dimensions, quantification and model size, did reveal differences when they were used in combination. Qualitative, small quantitative and large quantitative models were shown to differ with regard to the context in which they were used and their outcomes. However, these results do not shed much light on the mechanism through which group model building has an impact on participants. It is still unclear whether different mechanisms are at work or the same mechanism is at work in all of these categories, but to a different extent. As described before, alternative hypotheses on the ways in which modelling outcomes are brought about can be found in the literature (e.g. Andersen et al., 1997) but a comprehensive framework is missing.

In order to get a clearer idea on why modelling sessions have an impact on participants, it is useful to consider studies on other GDSS approaches. Since group model building has a number of similarities to GDSS, in particular to the soft operational research methods, the mechanism elements described in this field may also apply to group modelling. Section 2.2.2 mentioned four process aspects considered important in GDSS (McGrath, 1984; Pinsonneault and Kraemer 1989; 1990). The aspects refer to the following:

- type of decision supported, e.g. a vote or consensus;
- characteristics of communication: information exchange and influence attempts;
- interpersonal relations: cooperation in the group, domination by some members;
- structure of the decision process: standardisation and formalisation of group processes.

Most of these process aspects are considered in group model building as well. In a project particular techniques to structure the decision process are chosen, based on the type of decision central in that stage of the intervention. An effort is made to increase the quality of communication between participants, ensuring that everyone has an equal chance to contribute. An aspect that does not receive much attention in the methodological literature on group model building, is the attempt of one participant to influence another. Both the assumptions of modelling and facilitation seem to direct attention away from efforts of participants to influence others' opinions. In system dynamics, model construction is described as a process of joint learning. Facilitation focuses on an open discussion and equal contribution of all members, where influence attempts probably tend to be seen as attempts to dominate the group. However, since refinement of mental models or learning is considered an important outcome of the intervention, attempts to influence opinions seem to be central to the mechanism working in group model building.

Soft operational research methods discuss influence attempts more explicitly. Participants influence each other's opinions and goals in a process of negotiation. Eden describes how both the model and the facilitator need to support negotiation if a joint decision is to be reached. Eden (1989: 26) sees the facilitator as the designer and manager of the negotiation process, creating consensus and commitment. The role of the model in this is as follows (1992c: 805):

> *'It is the model that gradually emerges from the system of interacting arguments/ theories that create the negotiative device that is used to support strategy development workshops. The specific intention of working from cognitive maps of the 'everyday world taken-for-granted' is to enable strategic decision support to be provisioned by an 'owned' model.'*

In addition, soft operational research methods pay close attention to differences in power between participants. SODA (Eden, 1989) tries to manage the negotiation aspect of organisational decision making. In *Strategy development as a social process*, Eden (1992c) explicitly considers the social relationships which are part of the order in an organisation, and the social negotiation that accompanies discussion of complex problems. Eden separates the negotiated *social order* (social relationships) from the socially *negotiated order* (definition of reality). SAST (Mason and Mitroff, 1981) considers assumptions about important stakeholders involved in a strategic plan, and SSM (Checkland, 1981) addresses the autonomy of individual actors and aims for actions that are culturally and politically feasible for all parties involved. This resembles Eden's (1992a: 49) description of a wide band GDSS as a designed intervention that explicitly addresses process and content issues together. Process aspects go beyond facilitation of sessions and include organisational relations as well. Process and content are closely intertwined: 'Process management is informed by the analysis of content, and the analysis of content is informed by the analysis of process issues'. Eden expects an intervention that addresses the close relation of process and content to be more effective than an approach that considers either aspect in isolation. The cases described by Dutton and Kraemer (1985) and Appelman et al. (2002) illustrate how political dynamics influence the process and outcomes of modelling.

In conclusion group modelling can be seen both as a process of learning as well as negotiation. Negotiation involves attempts of participants to influence each other's opinions and directs attention to power differences (McGrath, 1984). In combination with the outcomes discussed in the last section, it seems that a conceptual model describing how information exchange and influence attempts relate to evaluations and cognitions can be of value in relating important factors in group model building. Before conceptual models from other disciplines are considered, context aspects are discussed in more detail.

### 4.2.4 Context

The context in which group model building is applied was described in section 2.4. Context is interpreted in a very wide sense. It includes not only objective characteristics of the organisation in which group model building is used, but also e.g. rules, norms and interrelationships (see section 2.6). In this study two contextual elements are most important: client and problem characteristics. The intervention is used in messy problems in organisations. Client characteristics refer to individual, group and organisational variables that determine how a complex problem is taken up. Similar to the description of outcomes above, I will limit the discussion here to the consequences of a complex problem for individual participants. Although the description of the context focussed on the organisational level, several effects on the individual level were pointed out. Managers lack the constructive power to deal with the analytical and social complexity of this type of situations. The biases in human decision making (section 2.2.2) that are operational in less complex situations, have an impact in these situations as well. Although there is frequently no shortage of data, information is dispersed among managers that each have a limited view on the problem (Vennix, 1996). Individuals lack the ability to oversee and process all relevant information. In addition to their expertise, managers are also involved in group model building because of their responsibility for the problem. In selecting the participant group, the power to implement conclusions is an important consideration. Since the problem is strategic and frequently affects a large part of the organisation, we may assume that managers do not only feel a personal responsibility, but also an urgency to deal with the problem. In conclusion, on the individual level the most important aspects of the context of group modelling are the inability to process all relevant information and the perceived responsibility and urgency to address the problem.

### 4.2.5 Summary

The following table summarises the main contributions of the discussion above to the conceptual framework on the impact of group model building.

| | |
|---|---|
| Outcome | evaluation in addition to cognition<br>conceptualisation of consensus |
| Mechanism | influence attempts and negotiation in addition to information exchange |
| Context | inadequate ability to process information<br>perceived responsibility and urgency |

*Table 4.1 Additions to a conceptual framework on group model building*

These additions need to be considered together with the context, mechanism and outcome elements that were identified in the foregoing sections. In the remainder of this chapter, an attempt is made to integrate the relevant variables for each category, leading to a summary and overall integration in section 4.6.

## 4.3 Outcomes: Ajzen model

On the individual level the effect of group model building can be described as an impact of communication on cognitive and evaluative structures, and finally on behaviour. The relation of cognition and evaluation to behaviour is studied in social psychology. So far, evaluative structures have not been explicitly defined. In the following, first a brief description of this concept is given. Second, a theory is outlined that attempts to explain behaviour. In the third part the concepts in the theory are linked to elements of group model building.

### 4.3.1 Background

In their review of social psychological research, Eagly and Chaiken (1993) concentrate on a particular cognitive structure whose relation to behaviour has been studied extensively. They refer to attitudes, which are distinct from other cognitive structures in their emphasis on evaluation. Eagly and Chaiken (1993: 1) use the following conceptual definition of attitude: 'a psychological tendency that is expressed by evaluating a particular entity with some degree of favor or disfavor.' The term *evaluating* is used in a broad sense and captures overt as well as covert responses, cognitive, emotional and behavioural. As a central topic in social psychology, the relation between attitudes and behaviours has generated some controversies. From the mid-1960s to the mid-1970s the idea that attitudes were poor predictors of behaviour was accepted widely. This assumption was supported by a number of studies showing no or weak relationships between the two concepts (e.g. Wicker (1969). According to Eagly and Chaiken, the popularity of research into the impact of behaviour on attitudes (e.g. Festinger, 1957) made it difficult to consider the causal link in the reverse direction. Reactions to these criticisms focused on the bias towards laboratory studies in Wicker's study, that mainly measured attitudes low in importance and involvement, on the situational barriers against expressing some behaviours (e.g. negative behaviour towards minorities) and on the level of aggregation of attitudinal and behavioural measures. Fishbein and Ajzen (1975) make an important contribution in this regard when arguing for compatibility between measures in order to ensure a substantial correlation. They suggest that general attitudes with respect to organisations, institutions, groups, individuals or ideas are good predictors of general behavioural categories summed over multiple behaviours. In contrast, specific attitudes will be good predictors of specific actions. Fishbein (1967) and later Fishbein and Ajzen (1975) present an influential model on the psychological processes by which attitudes influence behaviour, called the theory of reasoned action. A number of reviews take this model as one of the first and perhaps the most important model of the relation between attitude and behaviour (Eagly and Chaiken, 1993: 168; Van den Putte, 1993). The progress in understanding this relationship has led to a clearer idea on the limitations of its original formulation and proposals for revisions. I will first describe the original model and a number of possible additions.

### 4.3.2 The theory of reasoned action and theory of planned behaviour

In Ajzen and Fishbein's (1970) model, a central role is reserved for a specific attitude called the attitude towards behaviour. Attitudes towards behaviours are evaluations of the respondent engaging in a single behaviour or set of behaviours (Eagly and Chaiken, 1993: 164). The attitude towards a behaviour is the emotion for or against this action on a scale of good versus bad (Van den Putte, 1993: 5). Fishbein and Ajzen suggest that the attitude towards behaviour relates to behaviour through its impact on intentions. The attitude influences intention, which forms the basis for action. Ajzen (1991: 181) describes intentions as follows:

> *'Intentions are assumed to capture the motivational factors that influence a behaviour; they are indications of how hard people are willing to try, of how much of an effort they are planning to exert, in order to perform the behaviour.'*

In other words, intentions motivate the decision to act in a particular way. In addition to attitude toward behaviour, intention is also determined by the subjective norm. The subjective norm reflects a respondent's evaluation that significant others think he or she should engage in the behaviour. Significant others are the referents whose preferences a person takes into consideration in a certain domain of behaviour. In the previous section evaluations were described as cognitive, emotional and behavioural responses to a particular entity. The description so far makes it clear that in the theory of reasoned action emotional (attitude and subjective norm) and behavioural aspects of evaluation (intention and behaviour) are separated.

The theory also considers the cognitive foundation of attitudes. Attitudes are seen as a function of behavioural beliefs about consequences of an act. An example taken from one of the cases in this research might illustrate how beliefs and evaluations are related.

In this case, an important action is recruitment of additional personnel by a telecommunication provider. A person's attitude towards this action is formed on the basis of two sets of beliefs. The first is the *value* placed on outcomes of this action. The second belief concerns the *expected likelihood* that the action brings about this outcome. A possible outcome is e.g. an increase in innovation potential of the organisation. Let us suppose that a human resource manager positively values this outcome. Considering only this action (increasing recruitment), the chance that the valued outcome will be realised is the expected likelihood that recruitment leads to an increased innovation potential. If either innovation is valued more, or the relation between recruitment and innovation potential grows stronger, we expect the attitude towards recruitment to become more positive. In other words, values and expectancies combine to form evaluations. Fishbein and Ajzen (1975) propose to sum expectancy times value products over all beliefs to arrive at an indicator for behavioural beliefs.

Likewise, subjective norm is a function of normative beliefs and motivation to comply. A normative belief captures the perceived likelihood that a referent approves or disapproves of performing the behaviour. This is multiplied with the motivation to comply with the specific referent, and again summed over all salient beliefs. The human resource manager might have the following normative beliefs and motivation to comply. An example of a belief that important referents are in favour of performing the behaviour, is when the manager feels that the telecommunication provider's HRM department strongly favours increasing recruitment. If we also suppose that this person has a strong inclination to follow the opinion of the HRM department, his subjective norm towards increasing recruitment will be positive. Since both normative beliefs and motivation to comply are positive, we expect a positive subjective norm.

The theory of reasoned action was tested in a large number of studies and has generally yielded satisfactory outcomes (Eagly and Chaiken, 1993: 175; Van den Putte, 1993). However, a number of critics have argued against Fishbein and Ajzen's assumptions that a. the model offers a sufficient description of the direct causes of behaviour and b. other variables influence behaviour only through effects on concepts in the model. Proposals for additional factors that mediate the relation between attitudes and behaviour include perceived moral obligation, previous behaviour or habit, and perceived behavioural control. Perceived moral obligation represents personal beliefs about right and wrong (Eagly and Chaiken, 1993: 177). Fishbein and Ajzen (1975) exclude this concept from their model because they found it indistinguishable from behavioural intention. Van den Putte's (1993: 9) review, based on 150 groups, found that moral obligation added only little to the explained variance of intention. Authors have linked this concept to responsibility for performing the behaviour, demographic variables and personality traits, but no clear pattern emerges from the studies in which moral obligation does and does not make a contribution. Similarly, Ajzen (1991) denies that previous behaviour has a direct influence on behaviour. Although previous behaviour can be a very good predictor of future behaviour, this only occurs when all determinants are stable and thus behaviour is stable. Ajzen and Fishbein claim that most socially relevant behaviours are under volitional control, making habit a relatively unimportant addition to the model. Although Eagly and Chaiken (1993: 181) conclude that habitual behaviours have a larger role than expected by Ajzen and Fishbein, the overall importance of habit in predicting behaviour is unclear. Van den Putte again finds no consistent pattern in studies where habit does make a significant contribution.

The most important addition to the model is perceived behavioural control. Ajzen (1985; 1991) sees the theory of reasoned action as limited in domains were people have incomplete volitional control. Ajzen (1991) reviews studies showing the importance of people's confidence in their performance for both behavioural choices and the effort spent on performing. His extension to the original theory is called the theory of planned behaviour. Ajzen's new theory differs from the theory of reasoned action in that perceived behavioural control is added and related to two other factors in the model: to intention and to behaviour. Ajzen maintains that perception of control relates to behaviour to the extent that it reflects actual control. Only if a person's estimation of perceived behavioural control is accurate can it be used to predict the probability of actually performing the behaviour.

Perceived behavioural control is again determined by control beliefs, beliefs about the likelihood that one possesses the resources and opportunities thought necessary to execute the behaviour (Eagly and Chaiken, 1993: 187). First, there is the chance that a threat or opportunity will occur. In the previous example on recruitment, this could be the likelihood of a tight labour market on which few applicants can be recruited. Second, there is the degree to which the threat or opportunity is expected to influence implementation of the action. If a tight labour market prevents recruitment of employees, this lowers perceived behavioural control.

Ajzen's (1991) review of twelve studies shows improvements in predictions of behaviour after adding perceived behavioural control. Van den Putte (1993: 8) also finds moderate increases in explained variance of intention, and small increases for behaviour. In a recent publication, Ajzen (2001) reviews attitude theory and research published between 1996 and 1999. A number of studies tested the theories of reasoned action and planned behaviour. In general he finds that both theories do not differ much from models designed for specific behavioural domains, with regard to their ability to predict behaviour. In the following section we will look at the relation of the theory of reasoned action and possible additions, to decide which elements to include in a conceptual model on group model building impact.

### 4.3.3 Relation to group model building outcomes

The concepts in the theory of reasoned action and the proposed additions can be related to outcomes of group model building interventions. Behaviour in the theory of reasoned action and the theory of planned behaviour is similar to implementation of actions after a modelling intervention, in the sense that both are concerned with social behaviour. They are different in that implementation is more dependent on the organisational factors surrounding the individual decision maker. As the discussion of messy problems in the second chapter showed, no single manager has complete control over actions that will be undertaken with regard to the problem. Behavioural intention is very similar to commitment to future actions. Vennix et al. (1996) use Webster's dictionary to define commitment: 'an agreement or pledge to do something in the future, the state of being obligated or emotionally impelled.' This definition seems to express commitment to a specific act, but commitment to a modelling study's conclusions refers to a much more abstract and broader domain, which does not necessarily include a detailed plan for implementation (Rouwette et al., 2003, see section 3.5.5). In the remainder of this study, I will refer to commitment in the sense of Webster's definition above and use it interchangeably with intention.

*Attitude towards behaviour*

The attitude toward behaviour is closely related to the ends model described by Richardson et al. (1994). Eagly and Chaiken (1993: 191) discuss the similarities and differences between attitude-behaviour theories and theories on goal-oriented behaviour. Both approaches are compatible to some extent, as goals can be translated to the language of attitude models: 'Thus, for an attitude theorist, goals are end states or outcomes toward which people hold positive attitudes.' In formulating the theory of planned behaviour specifically for nonvolitional behaviours, Ajzen also contends that goals and behaviours are closely intertwined (Eagly and Chaiken, 1993: 186). He argues that even easily executed behaviours can be regarded as goals. Even for behaviours like voting in an election obstacles may arise (falling ill on election day), bringing it partially under control of nonvolitional conditions and thus more a goal than a simple behaviour. The attitude towards behaviour is formulated as an affective evaluation. Huz's (1999) operationalisation of a goals model resembles the cognitive foundation of attitude toward behaviour in beliefs about outcomes and evaluation of outcomes. Huz asks respondents to evaluate a list of system goals by rating their importance. What is missing in attitude-behaviour theories is the notion that goals can be ordered in a hierarchy (Eagly and Chaiken, 1993). Voting for instance involves numerous more simple behaviours such as putting on one's coat, finding the ballot paper, and walking to the polling station. Studies into goal-oriented behaviour show that the goal that is salient in relation to a particular action can vary considerably. People might formulate their intentions at different levels of abstraction, which is consequential for performance. In the example on voting, if the action sequence chosen to reach the goal 'voting' is suddenly blocked in some way (e.g. bad weather prevents walking to the polling station), a goal is formulated at a lower level and new behaviour chosen accordingly (e.g. the goal becomes 'reaching the polling station', which is also possible by car). I therefore conclude that attitudes are an important factor in group model building evaluation, are closely related to goals models, but care should be taken in choosing the appropriate level of abstraction for goals and attitudes. Earlier evaluations of group model building do not explicitly consider a hierarchy of behavioural outcomes, and this is not taken into account in attitude-behaviour theories either.

*Subjective norm*

The subjective norm, or the perception of the opinion of others, has a more complex relation to group model building outcomes than the elements of attitude-behaviour theories considered so far. Scheper (1991) sees consensus as the degree of similarity between the concepts, their essential properties, and relations between concepts, that different persons employ to describe a situation. This definition can be compared with the definition of subjective norm along four dimensions: a. the level of the definition (i.e. individual or intersubjective), b. its subjective or objective orientation, c. its mention of cognitive or affective factors, and d. the scope or degree of specificity of the definition. Scheper's (1991) characterisation places consensus on an intersubjective level. Subjective norm is different in that it is defined on the individual level. Consensus and subjective norm are similar in their emphasis on the subjective or personal definition of the important aspects of a situation. Consensus is based on concepts, properties and relations between concepts, which is cognitive in orientation. Subjective norm is defined as an affective evaluation, while its cognitive foundation in the theory of reasoned action is sought in beliefs about important referents. With regard to the scope of the definition, the definition of subjective norm seems to be more restrictive. Ajzen and Fishbein (1980: 76) suggest that a limited set of beliefs are considered when forming an evaluation, i.e. only those beliefs that are

salient. However, Eagly and Chaiken (1993: 111) question the assumption that evaluations are based upon an aggregation of salient beliefs only. Scheper essentially does not place any boundaries on the concepts or relationships that are considered.
In conclusion, consensus and subjective norm differ with regard to the level at which they are defined. I conclude that there are no major objections against an interpretation of subjective norm as the individual perception of the consensus view in a group. Placing it alongside attitude towards behaviour is in line with Faber's (1994) separation of cognitions on the personal and consensus view. It is noteworthy to consider how alignment relates to attitude-behaviour theory. In Huz's (1999) definition, alignment concerns agreement on means and ends which would translate to a decrease in variation of attitude, behavioural beliefs, perceived behavioural control and control beliefs.

*Moral obligation, habit and perceived behavioural control*

The first addition to the theory of reasoned action described above, perceived moral obligation, is not easily related to elements in group model building evaluation. Since empirical and theoretical results do not give many insights in the role of this concept in influencing behaviour, I will not consider it in the evaluation of group model building.
Similarly I will not consider habit as the importance of this concept for behaviour is unclear. Past behaviour however is included as a contextual factor in group model building interventions, since behavioural change is assessed by looking at differences between pretest and posttest measurements. Measuring past (pretest) behaviour is useful because it provides a clear benchmark against which to judge behavioural changes, without relying on self-reported changes.
Lastly, perceived behavioural control seems important as single participants are expected to implement behavioural changes after a group model building intervention, while a participant is not in complete control over a behaviour. Similar to attitude toward behaviour, a person's perception of control is an affective evaluation. The cognitive foundation in control beliefs and power of control beliefs again resembles Huz's (1999) operationalisation. Huz asks respondents to evaluate a list of functions or means of the system modelled[22], by rating their importance.

[22] The last element of Richardson et al.'s (1994) description of mental models, the means/ ends model (see section 2.5.3), has no direct equivalent in the Ajzen (1991) theory. The means/ ends model refers to relations between input and output of a dynamic system, and can therefore in part be related to the other stakeholders in the problem who control (elements of) the problem and to the relation between actions and outputs. In this sense the means/ ends model is related to normative as well as behavioural beliefs, but other aspects refer to the broader functioning of the system (e.g. its physical characteristics).

The factors considered important for evaluation of group model building discussed above, are all included in Ajzen's theory of planned behaviour. The following figure serves as an illustration of Ajzen's model[23]. In the remainder of this study I will refer to attitude, subjective norm and perceived control as 'evaluations' for reasons of simplicity.

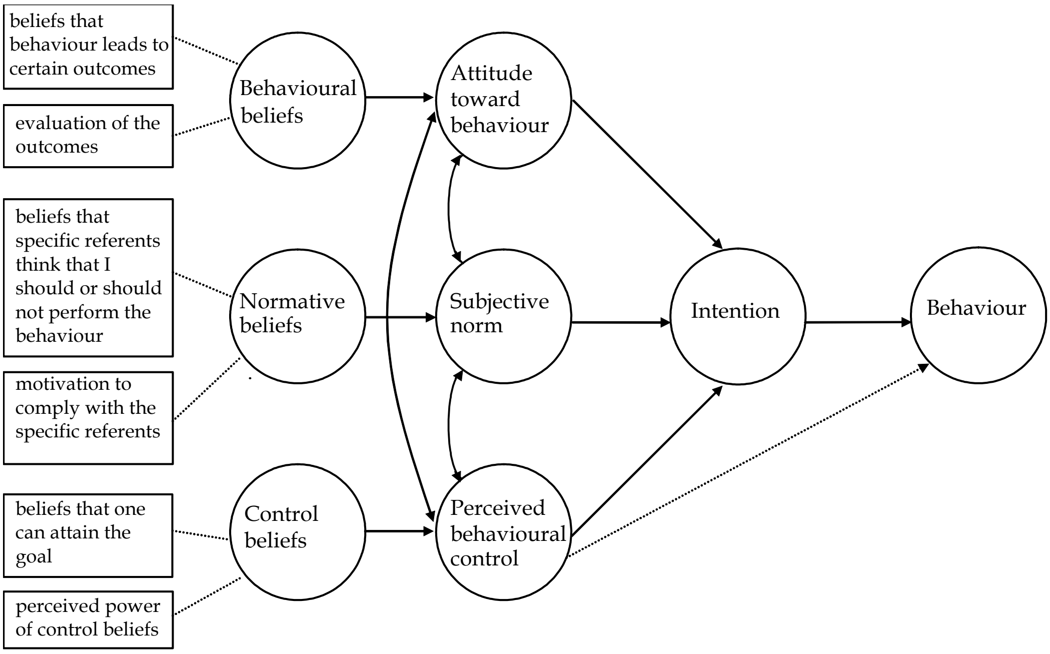


*Figure 4.1 Theory of planned behaviour (adapted from Ajzen, 1991: 182). The broken arrow at the right hand side indicates that perceived behavioural control is only predictive of behaviour if it is an accurate estimation of actual control*

Summarising the above, according to the Ajzen (1991) behaviour is influenced by intention and perceived behavioural control. Intention in turn is influenced by three sets of evaluations: attitude towards behaviour, subjective norm and perceived behavioural control. Each of these evaluations is formed on the basis of belief. Behavioural beliefs e.g. are a combination of beliefs that an action leads to a certain outcome, and the value placed on that outcome. In a similar way, subjective norm is related to normative beliefs and perceived behavioural control to control beliefs. Next mechanism elements are discussed.

[23] A system dynamicist may notice the absence of feedback between elements in the model. The model seems to depict the antecedent conditions to a single decision and in this sense includes variables commonly used in defining a rate equation: desired conditions and apparent actual conditions (Forrester, 1961). If behaviour is considered over a longer time period, its consequences may lead to changes in apparent actual conditions and urge the actor to take a different course of action. This feedback is evident in the extended attitude – behaviour theories described by Eagly and Chaiken (1993).

## 4.4 Mechanism: persuasion theories

The mechanism elements identified as important in previous sections are modelling, facilitation and influence attempts or negotiation. In the last section evaluations were described as the most important outcome elements of group model building. In the following I first describe two theories of evaluation change and then discuss the connection to modelling, facilitation and influence attempts.

Eagly and Chaiken (1993) discuss two important models of evaluation formation and change, the Heuristic Systematic Model (HSM, Chaiken et al., 1989) and the Elaboration Likelihood Model (ELM, Petty and Cacioppo, 1986). Although these models concentrate on attitude change, I assume that similar processes operate in changing subjective norm and perceived behavioural control. In HSM and ELM two routes are available in which evaluations can be changed. The first route route consists of understanding and evaluation of arguments. A persuasive message is received and understood, arguments in the message are identified, contrasted with existing knowledge and judged on their validity. This route is termed the systematic (HSM) or the central route (ELM). Following the second route evaluations are changed on the basis of simple decision rules or heuristics (e.g. 'the expert's information can be trusted'). Both the HSM and ELM refer to this as the peripheral route.
The content of both information and heuristics can be either negative or positive, leading to a change in evaluations in a negative or positive direction. For example when during modelling a new positive outcome of an action alternative is identified (a positive argument) we can expect the attitude towards that action to become more positive. According to the HSM and ELM, the decision which route will be used depends on the person's motivation and ability to process information. If both motivation and ability are high, the central route will be more influential in changing attitudes. Motivation is high when e.g. the situation is high in personal ('outcome') relevance. When a person is already knowledgeable about the subject, ability to process information is increased.

Contrasting these routes available for evaluation change and the practice of group modelling, it seems clear that modelling and facilitation operate to make as much use of the first route as possible. The aim of group model building is to integrate and structure available information about a problem, bypassing the heuristics used in 'traditional' decision making. Thus modelling primarily affects the ability to process. Since participants are invited to contribute to group modelling sessions based on their expertise or stake in the problem, motivation can also be expected to be high. This is discussed further in the following section on context. Influence attempts and negotiation can be placed in HSM and ELM as well. Participants can attempt to influence each other's opinions both by exchanging information (the central route) and by using heuristics such as their power or status (the peripheral route). To the extent that the participant group operates as a cohesive group or team, the influence of heuristics on participants' evaluations is limited because the influence of power and status differences will be limited. Vennix et al. (1996: 52) see the relation between persuasion routes and group model building as follows:

> *'We may assume that the managers in question are relatively knowledgeable about the subject. However, other factors, such as message comprehensibility and attention of the subject, have to be sufficient to enable a subject to consider all relevant information. Group model-building is generally helpful to process and integrate a large amount of information, provided that the facilitator succeeds in creating a sphere of open and supportive communication in which mental models can be shared and explored freely.'*

Influence attempts in group model building can therefore be assumed to operate largely through the central route.

Negotiation can be related to persuasion routes in a similar way. Negotiation can be seen as a process of aligning goals and resources in an attempt to come up with an action plan. The use of the central route to change ideas on goals and means is reflected in Andersen et al.'s (1994) description of design logic and operator logic. Andersen et al. study the information that people use in deciding on interventions in a system, i.e. to select the means to reach a particular goal. They find that operator logic or strategic insights are more effective in shaping interventions than elaborate knowledge on system design. This can be translated to the goal that is salient to a person trying to manage a system. If a goal low in the hierarchy such as a specific intervention in a system is salient, information on the consequences of this action (operator logic) is considered most relevant to the task and most effective in changing behaviour. If higher level or strategic goals are salient such as changing behaviour of the complete system for the better, more abstract knowledge on system design (design logic) will be more instrumental than detailed knowledge on specific interventions. Going back to the previous example on voting, a lower level goal would be 'find the ballot paper'. For a particular person, the related operator logic might be 'search in cupboard' which would enable him to reach this goal in most instances. For the higher level goal 'voting' many barriers can be imagined: reaching the polling station by walking is prevented by bad weather or a broken leg, driving is impossible as the car is being repaired. Here information on the different action alternatives and their consequences, i.e. the 'design of the system', would be more helpful. This again underlines the importance of carefully considering which goal has to be selected[24]. As the example shows, operator and design logic both refer to information on how to reach a particular goal, and can therefore be seen as central route persuasion.

In the foregoing a number of reasons were described for assuming that in group model building the central route to persuasion is operational. Before participants will change their opinions, another factor needs to be present: arguments. Exactly what makes information an argument that potentially changes a receiver's opinion, is only studied in general terms (Petty and Cacioppo, 1986). In short, information needs to be new and relevant to the receiver if it is to be effective in changing evaluations. This highlights the role of counterintuitive insights that are sometimes gained in system dynamics interventions (Forrester, 1975). Through their impact on evaluations and intention, these insights can be expected to affect implementation. Two characteristics of arguments are important in this study: argument quality and persuasive content. The first refers to degree to which arguments are new and relevant to the receiver (Fishbein and Ajzen, 1975). The latter refers to whether arguments are positive or negative with regard to attitudes, subjective norms or perceived behavioural control. The previous example of the model on the Dutch fleet (Vennix, 1995) can clarify this. To representatives of the Dutch ports, the relation between size of the Dutch merchant fleet and size of the Dutch ports can be said to constitute new and relevant information, which has a persuasive content. The information is new as the relation was not considered explicitly before. It is highly relevant, as the size of the Dutch ports is an important consideration to representatives of this department of the Ministry of Transport. The persuasive content follows from the fact that a decrease of the Dutch merchant fleet corresponds to a decrease (over time) in the size of Dutch ports and has several other negative consequences for Dutch ports. The information thus forms a positive argument for increasing (or not decreasing) the size of the Dutch merchant fleet. The attitude and subjective norm towards increasing the size of the Dutch fleet are therefore expected to grow more positive[25].

[24] This relates to the contention of Richmond (1997) that the main purpose of the strategic forum (see section 2.3.6) is to check the consistency of strategy. He finds that modelling leads to change in strategies or operating policies, but only seldom to changes in objectives or the mission statement. Again this reflects a hierarchy of modelling goals. Whether goals higher in the hierarchy are less likely to change than lower level goals, is an empirical question which will be addressed again in chapter eight.

[25] The example does not include any information on the degree to which participants can steer size of the Dutch merchant fleet, which means that the impact on perceived behavioural control is not clear. Section 5.4.2 will go into the relation between arguments and changes in evaluations.

The conceptualisation of communication described here highlights its persuasive character. However, it does not specify which metacodes or codes will be used to assess the meaning of a communication (cf. Scheper, 1991). Scheper expects situational constraints, such as the theme of the discussion, to be influential in this respect. Although the HSM and ELM have little to add in this respect, they are in line with Scheper's emphasis on subjective interpretation, by considering individual levels of motivation, ability, prior knowledge and evaluations. I conclude that HSM and ELM and Scheper's communication model are not contradictory, and the main benefit of the first one is their delineation of persuasive elements. After this section on mechanism, the next section addresses contextual variables.

## 4.5 Contextual variables

The models discussed in the previous sections allow us to identify the main contextual variables. At the individual level, the most important aspects of the context of group modelling are the inability to process all relevant information and the motivation to process information. From the discussion on mechanism elements in the previous sections, it appears that both of these factors can be related to persuasion theories. As described above, the ability to process information is influenced by the degree of support of the decision making process. The main contribution of group model building to the decision making process (and therefore the main mechanism element) is to increase the ability to oversee and relate all relevant information. The second factor in the persuasion theories, motivation to process information, is an element of the context of the group model building intervention. The degree of motivation is determined by organisational and problem characteristics. If the problem is perceived as important, a high motivation to process information can be expected.

## 4.6 Integration and remainder of the study

The following figure summarises the most important elements of context, mechanism and outcome discussed in this chapter.

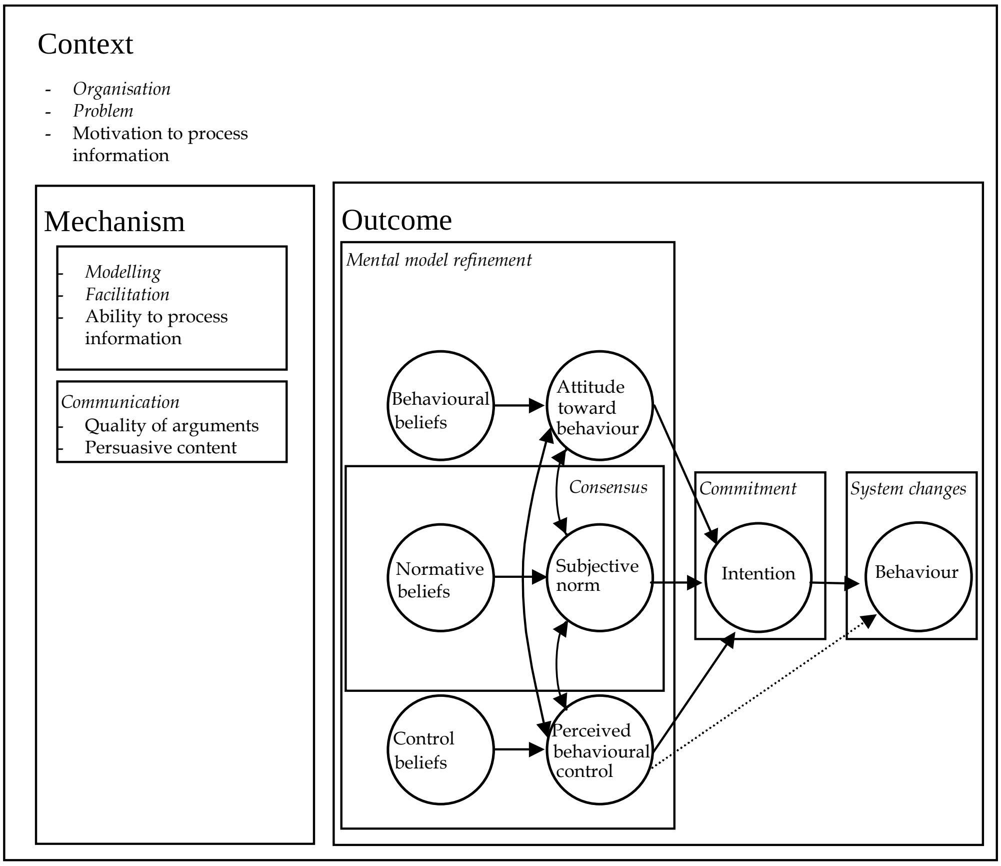


*Figure 4.2 Central variables in the conceptual model and their relation to context, mechanism and outcome elements (context, mechanism and outcome elements depicted in italics)*

The variables included in the figure allow us to elaborate the context – mechanism – outcome elements reported in chapter two. On the basis of the group model building literature, the most important context factors described in chapter two were organisational and problem characteristics. In the figure 'motivation to process information' is added. If group model building is seen through the lens of persuasion theories, problem and organisation elements are important in so far as they influence the motivation to process information.

In chapter two, modelling and facilitation were considered the main mechanism elements operational in group model building. As described in section 4.4, modelling and facilitation can be said to support the ability to process information. The other mechanism element is communication, which boils down to the exchange of arguments. Two aspects of arguments are important in this study: argument quality and persuasive content. Both can be expected to influence the direction of evaluation change.

With regard to outcome variables, the group model building literature described in chapter two focussed on system changes and system results, improvement of communication quality, creation of consensus, and refinement of mental models (see figure 2.5). Communication, in chapter two discussed as an outcome variable, changes to a mechanism variable in this chapter. The remaining outcome variables can be related to the concepts in the Ajzen model, as described in section 4.3.3. Implementation of system changes is related to behavioural changes. Commitment is similar to intention. Mental models relate to all of the three evaluations and corresponding beliefs in Ajzen's model: goals models can be equated with attitudes and outcome beliefs, means models are captured by perceived behavioural control and control beliefs. Subjective norms and normative beliefs are on one hand an element of mental models and on the other hand represent consensus. System improvement is not captured in the Ajzen model which focuses on the individual level, but must be the results of individual behaviour to implement a decision. These considerations allow us to reformulate the context – mechanism – outcome relations reported in section 2.6 (see table 2.5) as depicted below.

| *Context* | | *Mechanism* | | *Outcome* |
|---|---|---|---|---|
| Stakeholders in a highly complex problem who are motivated to engage in a decision making process | + | A method that increases ability to process information and identifies arguments that are either positive or negative | = | Change in beliefs and evaluations, intentions and behaviour of participants |

*Table 4.2 Basic context, mechanism and outcome elements*

In the remainder of this study the following topics are addressed. In chapter five, the conceptual framework is used to derive hypotheses for the empirical part of this study. The hypotheses will be tested in five applications of group model building to organisational problems. The problems, organisations and intervention process for each case are described in chapter six. Chapter seven presents the analysis of data and results. In chapter eight the conclusions of this study are presented.

# Chapter 5 Hypotheses, research design and operationalisation

## 5.1 Introduction

In the previous chapters approaches to intervene in group decision making in a complex problem were described. Group model building was selected as the focus for this study. Chapter two described how group model building combines insights from system dynamics modelling and group facilitation. In a situation where managers are confronted with complex problems, the approach can help to elicit and integrate insights and identify actions to alleviate the problem. In particular, group model building is expected to increase quality of communication between managers involved in the problem, refine mental models and create a consensus view, and finally foster implementation of conclusions and system improvement. In chapter three the system dynamics literature was surveyed to identify applications of group model building and reported outcomes. In many case reports the approach seemed to have helped in bringing about the outcomes listed above. The literature survey also revealed a conceptual confusion concerning outcomes such as consensus. In addition, the system dynamics literature offers few insights into, for instance, the relation between communication and mental models, or the effect of group model building on quality of communication. The major conclusion for future empirical studies was that the relations between separate goals of the intervention and the effect of intervention elements on goals, need to be clarified. In the last chapter literature from a broader field (soft operational research and psychology) was used to develop a conceptual framework to this end. The framework centres on the determinants of individual behaviour. The main elements are derived from Ajzen's (1991) theory on the relation between attitudes and behaviour, and from persuasion theories which address the impact of communication on attitude change.

In this chapter the conceptual framework is used to derive research hypotheses. For operationalisation and measurement of variables, standard approaches in attitude research are adapted to the specific setting in which group model building is applied. In section 5.2 the conceptual framework is used to formulate hypotheses. Section 5.3 addresses the research design and considerations on validity. Operationalisation and measurement are the topic of section 5.4. Section 5.5 describes the construction of variables. Section 5.6 concludes this chapter with a short summary.

## 5.2 Research hypotheses

This study centres on change in managers' evaluations of actions in a complex problem, due to participation in a group model building intervention. In this study, group model building is seen as an exchange of persuasive communications leading to changes in participants' evaluations. Theories of persuasion (Petty and Cacioppo, 1986; Chaiken, Lieberman and Eagly, 1980) are helpful to identify the conditions in which evaluation change is likely to take place. Ajzen's theory of planned behaviour (1991) is used to formulate expected impacts of evaluations on behaviour. The literature scan in chapter three showed that modelling is capable of changing participant's ideas and behaviour, and that the type of intervention (e.g. a qualitative or quantitative model) has an impact on outcomes. From these theories it follows that the main issues to be addressed in the hypotheses are the following:

a. Are the conditions for evaluation change present in group model building? Only if participants are motivated and able to process information, and persuasive arguments of high quality are exchanged, can they be expected to change their evaluations.
b. Do the arguments exchanged in modelling have an impact on variables in the Ajzen model? A basic approach to studying modelling from the perspective of the Ajzen model, would be to see if there is a direct relation between arguments exchanged in modelling and variables in the Ajzen model. However, since the Ajzen model includes different beliefs and evaluations that are related in complex ways, for several relations intervening variables can be expected. According to the Ajzen model, behavioural beliefs are for instance an intervening variable in the impact of arguments on attitudes. In the analysis of results, the direct effect and the intervening effect of other variables will be considered. In order to keep the formulation of hypotheses as simple as possible, the hypotheses on the Ajzen variables will refer to the conclusions of the modelling project (e.g. participants' attitudes change in the direction of the conclusions of the modelling project) and intervening variables will not be mentioned explicitly.
c. To which extent can context – mechanism - outcome patterns be found in the data in this study? In reviewing group model building evaluation studies (chapter three) it became clear that specific combinations of context and modelling mechanism are likely to produce certain outcomes. The use of a qualitative model in a messy problem was for instance less likely to lead to consensus (compared to the use of a quantitative model in a less messy problem).

In the following sections these three central issues are formulated as hypotheses.

### 5.2.1 Conditions for evaluation change

The persuasion models described in the previous chapter (Petty and Cacioppo, 1986; Chaiken, Lieberman and Eagly, 1980) specify two routes through which evaluations may change. Using the central route, the information and arguments in a communication are screened. The peripheral route focuses on heuristics associated with a message. The central route was chosen if motivation and ability to process information is high. From the description of group modelling it became clear how facilitation operates to disentangle process and content issues, ensuring that arguments are elicited and integrated in an overall view of the problem. This is expected to lead to a separation of information from other characteristics of the message, for instance who the message originated from or its initial comprehensibility. The model works to visualise variables and their relationships. In this way modelling has its foremost impact on the ability to process. The motivation to process is affected by other factors, for instance the perceived urgency of the problem. However, following the persuasion models, motivation will need to be high in order for participants to consider information. The first hypothesis is therefore the following.

1) *Participants in group model building are motivated to process information.*

Above the second important condition for evaluation change was described: ability to process information. The second hypothesis addresses the processing of information. An additional question on process is how participants evaluate group model building in comparison to a traditional decision making approach. The use of group model building in a complex problem presents a situation for which it is difficult to convene a control group. This issue is discussed more extensively in the following section on research design. Alternatively, a subjective evaluation introduces to a certain extent a baseline for establishing group model building effects. This leads to the following hypothesis on process:

2) *Group model building leads to a high quality decision making process, i.e.*
    a. *high ability to process information;*
    b. *positive evaluation compared to traditional meetings.*

In addition I will look into the contribution of the main elements of group model building to overall effects. Differences in evaluations of elements of the intervention can help explain different evaluations of cases. At the highest level, the effect of group model building can be contributed to the model or to facilitation during the sessions. On a more concrete level, participants can be asked to estimate the contribution of specific components of group model building, e.g. the use of causal loop diagrams or the opportunity of open discussion, to overall results. The elements of the intervention that will be addressed in this study are described in section 5.4 on operationalisation.

The third condition for evaluation change to take place concerns the arguments exchanged over the course of the intervention. As we saw from the discussion in the last chapter, the system dynamics methodology includes many tests on content quality in the form of validity and sensitivity tests. This leads us to expect that group model building is instrumental in providing arguments for evaluation change. Following the central processing route evaluations are changed on the basis of a careful consideration of arguments. This expectation on persuasive arguments translates to the third hypothesis:

3) *In group model building arguments for evaluation change are exchanged.*

### 5.2.2 Impact on Ajzen variables

The discussion so far focussed on conditions for evaluation change: motivation and ability to process information and arguments. A further question is whether these variables are related to change in the variables in the Ajzen (1991) model. The following hypotheses will address the relation of the *conclusions* of the modelling sessions to change in beliefs, evaluations, intentions and behaviour. The exact operationalisation of the independent variable is addressed in section 5.4. The first variable in the Ajzen model that will be considered are the behavioural beliefs. The conclusions of the modelling sessions are expected to function as a persuasive communication, leading participants to identify new outcomes of their actions and thereby changing behavioural beliefs. This translates to the prescriptive propositions in the previous chapter on increased refinement in participants' goals models. The hypothesis on behavioural beliefs is the following:

4) *Participants in group model building change their behavioural beliefs about actions in the problem in the direction of conclusions of the modelling project.*

In group model building the group of participants is selected in such a way as to represent all important stakeholders in a problem. We can therefore assume that for an individual participant in the group the other participants serve as his or her referents. Vennix, Akkermans and Rouwette (1996) describe two extreme situations that may arise. One extreme is that there is a complete divergence of opinions on a particular action. In this situation the normative beliefs of participants can be expected to diverge as well. The other extreme is a complete consensus on the necessity of implementing a certain action. In that case participants' normative beliefs can be expected to converge. This translates again to the prescriptive propositions in the previous chapter on increased refinement in participants' mental models and increased consensus. This can be phrased as follows:

5) *Participants in group model building change their normative beliefs about actions in the problem in the direction of conclusions of the modelling project.*

The final set of beliefs, beliefs with regard to the control over actions, is expected to change during a group model building intervention as well. In case a participant perceives more opportunities or less barriers for carrying out an action, she will perceive more control over actions. Since system dynamics modelling is concerned with finding leverage points in the system and checking their impact in policy experiments, control over actions is certainly addressed during the intervention. If the feasibility of available courses of action is analysed and the most promising actions end up in the study's conclusions, this can be expected to increase perceived control. In the prescriptive propositions mentioned in the previous chapter, this boils down to increased refinement in means models. The hypothesis on control beliefs reads as follows:

6) *Participants in group model building change their control beliefs about actions in the problem in the direction of conclusions of the modelling project.*

Next we turn to evaluations: attitude, subjective norm and perceived behavioural control. In the foregoing hypotheses a number of reasons for the expectation that participants' evaluations will change, have already been outlined. Attitudes are affected if a participant learns about previously unknown outcomes of an action in the system. Subjective norms are changed if referents are perceived to change their position and are seen to endorse an action not expected beforehand. Perceived control is changed if barriers to an action are perceived to change in importance. Expected changes in evaluations are reflected in the prescriptive propositions on increased refinement in participants' mental models. Increased consensus is reflected in change in subjective norms. This leads to the following three hypotheses:

7) *Participants in group model building change their attitude toward actions in the problem in the direction of conclusions of the modelling project.*

8) *Participants in group model building change their subjective norm toward actions in the problem in the direction of conclusions of the modelling project.*

9) *Participants in group model building change their perceived behavioural control toward actions in the problem in the direction of conclusions of the modelling project.*

The three hypotheses above specify expected changes in the determinants of behavioural intentions. If the three determinants change in the same direction, a comparable shift in intentions can be expected as well. The situation is conceivable where a participant evaluates outcomes of a certain action negatively, looking at how an action will affect himself or his department, while other participants see benefits to the proposed action. In this situation the participant would perceive a consensus view divergent from his personal view. However, the question then becomes whether the personal goals outweigh perceived benefits for the other parties, or the other way around. In the second chapter a number of case studies were presented that showed how system dynamics was helpful in overcoming departmental biases and creating common goals (Hall and Menzies, 1983; Vennix, 1996). By showing the interdependence of system elements, group model building is likely to identify actions that benefit most stakeholders. The related prescriptive proposition is that effective group model building should result in more alignment on intentions. This leads to the following hypothesis:

10) *Participants in group model building change their intention toward actions in the problem in the direction of conclusions of the modelling project.*

Likewise, intention and perceived control will need to change in the same direction for behaviour to be impacted. Again, we assume that system dynamics will be helpful in generating policy interventions that are feasible and actionable, so that individual participants feel in control of and committed to implementation. The related prescriptive proposition is that effective group model building should result in implementation of conclusions. This amounts to the following:

11) *Participants in group model building change their behaviour in the problem in the direction of conclusions of the modelling project.*

### 5.2.3 Context-mechanism-outcome patterns

The literature analysis in chapter three identified the following differences between configurations or model formats:

- Context: qualitative models are more likely than quantitative models (small and large) to be used in messy problems, i.e. problems that are new to the people involved, have widespread consequences and involve a broad range of interests; configurations do not differ with regard to organisational background or problem importance.

- Mechanism: compared to small quantitative models, large quantitative models take longer to construct and involve a larger number of participants; configurations do not differ with regard to communication quality.
- Outcome: qualitative models are less likely than quantitative models (small and large) to lead to commitment, consensus and system changes; configurations do not differ with regard to insight or behavioural change.

Chapter four (see figure 4.2) described the relation of the elements mentioned above to variables in the persuasion models and Ajzen (1991) model. Communication quality can be translated to ability to process information and argument quality. Commitment can be rephrased as intention, consensus is found in the Ajzen model as normative beliefs and subjective norms, while system changes has no equivalent in the Ajzen model. Insight is reflected in behavioural, normative and control evaluations and beliefs. Finally, behavioural change has a clear equivalent in the Ajzen model. The differences in configurations are captured in the following hypotheses:

12) *With regard to the context of group model building,*
   a. *qualitative models are more likely to be used in messy problems than quantitative models;*
   b. *model types do not differ with regard to organisational characteristics;*
   c. *model types do not differ with regard to problem importance.*

13) *With regard to the mechanism of group model building,*
   a. *large quantitative models take longer to construct than other types of models;*
   b. *large quantitative models involve a larger number of participants than other types of models;*
   c. *model types do not differ with regard to ability to process information;*
   d. *model types do not differ with regard to argument quality.;*

14) *With regard to the outcome of group model building,*
   a. *participants in quantitative modelling projects and participants in qualitative modelling projects do not differ with regard to changes in behavioural beliefs;*
   b. *participants in quantitative modelling projects and participants in qualitative modelling projects do not differ with regard to changes in attitudes;*
   c. *participants in quantitative modelling projects change their normative beliefs more than participants in qualitative modelling projects;*

*d. participants in quantitative modelling projects change their subjective norms more than participants in qualitative modelling projects;*
*e. participants in quantitative modelling projects and participants in qualitative modelling projects do not differ with regard to changes in control beliefs;*
*f. participants in quantitative modelling projects and participants in qualitative modelling projects do not differ with regard to changes in perceived behavioural control;*
*g. participants in quantitative modelling projects change their intentions more than participants in qualitative modelling projects;*
*h. participants in quantitative modelling projects and participants in qualitative modelling projects do not differ with regard to changes in behaviour.*

After specifying the hypotheses to be tested in this study, we are now in a position to consider the benefits and drawbacks of different research designs.

## 5.3 Research design and validity

### 5.3.1 Research design

In the second chapter, two different orientations to group decision support were described: the US GDSS approach that focuses on information exchange during a meeting, and the wide-band or soft operational research approach that takes other influences on decision making into consideration as well. Group model building was seen as a representative of the second orientation. The difference in intervention designs and aims of wide-band and US GDSS is not without consequences for the research designs preferred by the two communities. Most early US GDSS research employ a quantitative experimental design, although in the past decade the number of field studies and qualitative case studies has increased (Zigurs, 1993: 113). Early studies in this field typically compared three groups: a computer-supported, a manual, and a baseline group. The computer-supported group uses the GDSS that is being tested. Manual groups are provided with a paper-and-pencil version of the system, while baseline groups do not receive any instructions or support and are left to interact freely. As Zigurs (1993: 119) notes, these comparisons are useful for studying relatively simple systems. For more complicated group support methods it becomes more difficult to determine what a manual comparison group should be. She concludes that classical control group testing is inappropriate in some cases and may prove very problematic in field studies. In wide-band GDSS Eden (1992a) makes an even stronger assertion when saying that these systems can only be tested when applied to a messy problem. This means that field studies should be used and control groups are difficult to convene, as stakeholders in a messy problem can hardly be considered a homogeneous population. He cites four arguments against using experimental designs for evaluating wide-band GDSS (Eden, 1992a: 7):

> *'Why should controlled experiments be inappropriate and dangerous in evaluating the UK [wide-band] systems? The overriding reason is that the systems were designed to address the complexity facing real managerial teams by: i) seeking to work with clients who pay the price for using the GDSS by cash, risk their own presentation of self, have to negotiate with a sponsor to use a consultant and their method, and most importantly live with the consequences; ii) the consultant having to negotiate expectations and a contract; iii) creating support that enables a group to work with one another after the GDSS workshop; iv) embedding commitment act – both emotional and cognitive. This means that researching with any groups that do not have the above characteristics wholly discounts evaluating some of the primary characteristics of the GDSS method.'*

In contrast, Scheper (1991: 212) does see merit in using an experimental design in evaluating wide-band GDSS. In line with his theory of communication described before, he distinguishes between a content and a process effect on the outcome of a GDSS. In his opinion, a GDSS represents an attempt to affect group processes in such a way that the group accomplishes its tasks. Therefore the proper effect of a GDSS is the effect on group process alone and this should be isolated from the content effect. He proposes an experiment in which the treatment group participates in a GDSS workshop, while the control group only receives a written text containing all the arguments exchanged in the workshop. He does not consider the assignment of participants to the control or experimental condition problematic, and argues for the use of randomisation if the size of the group is adequate.

In conclusion, authors from different GDSS strands argue for the testing of systems in applied settings because the intervention is complex and takes into account many aspects of the group that is supported. Although a field study prevents the use of randomisation, it does not completely preclude the use of a control group. The practical difficulties of convening a control group are illustrated by the study of Verburgh (1994: 66). In his intended design, participants would be divided in two groups, both of which would be offered the treatment but at different times. In this way the group receiving the later treatment could serve as a control group for the first. However, the participating organisation insisted that all participants took part in the intervention at the same time. In contrast, Huz (1999: 39) does succeed in employing a three factor field study design but assignment to conditions is not completely random. Also, this raises the question to which extent groups were comparable, for instance with regard to the relations between participants.

The survey design has been used for wide-band GDSS (for instance McCartt and Rohrbaugh, 1989; Vennix et al., 1993) and US GDSS (Zigurs, 1993). Eden (1992a: 8) finds the use of questionnaires problematic for two reasons. The management teams that are supported are generally difficult to treat as research subjects and 'rarely cooperate in completing forms.' In addition, the richness of the problem context is inadequately captured by questionnaires. Eden prefers the use of open ended methods as they allow participants to formulate what happened during and after the intervention for themselves.

Not surprisingly, researchers on wide-band GDSS (Eden, 1992a) and US GDSS (Zigurs, 1993) alike, call for a larger role of qualitative research and case studies, where the intricacies of the setting are captured and participants describe outcomes in their own words. From the beginning of the field, wide-band GDSS have typically been researched in case studies, as can be seen from the study by Checkland and Scholes (1990) and the review of group model building cases in the first chapter. In these cases it is most often the consultant who performs the role of evaluator, since he or she is the one who works most closely with the client on often confidential matters (Eden, 1992a: 9). This approach incorporates elements of action research (Schein, 1987). However, a sole reliance on this type of design is not without dangers. In case studies a large role is reserved for retrospective self-reports which suffer from a number of methodological weaknesses. Vennix (1990) and Doyle et al. (1998) draw attention to four issues here. First, the approach is subjective in that it relies on the opinions of consultants and participants. Reported change might however not be identical to actual change because of the operation of a number of biases. For example in an early evaluation of a system dynamics intervention, Weil (1980: 273) warns against mutual face saving operations which could lead both client and consultant to play down the importance of negative outcomes.
Secondly, a retrospective approach to a great extent draws on participants' recollections. Recollection might be disturbed, especially if data are gathered some time after the study is completed (Vennix, 1990: 67; Wolfe, 1985). Eden (1992a), although in favour of capturing GDSS outcomes in participants' own terms, questions the reliability and validity of their recollections. The strategic decisions addressed by GDSS are generally made by groups of shifting sizes and composition and depend on other decisions made in other parts of the organisation. Participants might restructure memories in order to enhance their own positions or their efficacy, or less obtrusively when they engage in wishful thinking or see the past through 'rose tinted glasses'. A more direct measurement of changes, involving an assessment at two points in time, is therefore needed.
Third, disentangling the effect of the intervention from other developments in the problem is difficult, since experimental control is low in a case study. Vennix (1990: 64) mentions the increasing difficulty of measuring intervention effects going from impact on mental models, to decisions and eventually policy impacts or results of

system changes. At each step additional factors come into play that might affect results. It is doubtful whether participants are able to accurately rule out alternative explanations for changes at any of these levels, particularly if they know the researcher's expectation (Eagly and Chaiken, 1993: 72).
Fourth, one way of circumventing these problems might be to use data that are gathered as part of the intervention. However, Doyle et al. (1998) warn against using data gathered through the intervention method for assessing intervention impacts. Consider the following example. Often a group model building intervention is started by interviewing participants using causal modelling. In these interviews mental models are typically elicited but also structured, and thereby changed, as well. The value of this type of interviewing as an accurate pretest of knowledge is therefore questionable. In sum, although a case study is high on external validity, a number of threats against internal validity remain to be dealt with.

The foregoing represents two extreme positions on the issue of design choice: an open approach taking into consideration a wide range of aspects of the problem situation versus a more restricted design in which the effect of the intervention can be more easily isolated. In the previous chapter I followed the idea proposed by Pawson and Tilley (1997) to organise a framework on group model building effects in terms of context, mechanism and outcome. In a similar fashion, these authors argue that design choice should optimise the chance of discovering further specifics of intervention context, mechanism and outcome. It seems that multiple research methods should be used to overcome the disadvantages of particular approaches. For US GDSS, Zigurs (1993: 115) draws the same conclusion: 'In the end, it is the judicious combination of multiple methods that has the most potential.' From the discussion above the following conclusions are important for estimating the impact of group model building on participants' evaluations:

- In evaluating a completed group model building intervention, a field study involving a client group working on a real problem needs to be involved. Although other groups (e.g. students) in a laboratory setting might prove useful for testing specific elements of the method, the complete process can only be tested in conjunction with a real and messy problem.
- In order to assess real change instead of (potentially biased) reported change, measurement at at least two points in time is needed.
- Randomisation in a field test of GDSS has proven to be very difficult. Convening a control group is complicated by the impossibility of finding a matching group with respect to all important variables, e.g. problem complexity, problem urgency and stakeholder relations.
- Assessment needs to include a qualitative element to allow participants to phrase outcomes in their own language.

- Assessment also needs to go beyond participants as information sources, since their reports might be biased for a number of reasons.

Weighing the considerations above, the one group pretest posttest design (Cook and Campbell, 1979: 99) seems to be the best answer to the practical and methodological demands on evaluating group model building. In order to be able to identify differences between specific projects, multiple interventions will be evaluated. Instead of trying to convene a control group, other bases for comparisons will be used, i.e. outcomes of unsupported groups as reported in the literature and participants' subjective comparisons of supported and unsupported processes. This design can be illustrated as follows.

| | | |
|---|---|---|
| $O_1$ | $X$ | $O_2$ |

*Figure 5.1 Research design*

The design consists of pretest observations of group ($O_1$) which subsequently receives a treatment ($X$), after which posttest observations ($O_2$) are made. In this study the group consists of several subgroups, each representing a single group model building intervention. The arguments for aggregating the subgroups into one treatment group will be discussed in the section on results. Cook and Campbell (1979) list a number of weaknesses of this design, which will be addressed in the following section on validity.

### 5.3.2 Validity

In this section the weaknesses of the one group pretest posttest design, as described by Cook and Campbell (1979) are discussed. A number of measures are described that serve to remedy threats to validity. The first weakness discussed by Cook and Campbell is history: events other than the intervention causing a change in the dependent variable. This can be checked by asking participants how changes between pretest and posttest came about, although care has to be taken to avoid the biases in retrospective self-reports. In this study changes in evaluations, beliefs, intentions and actions are all potentially influenced by history. For evaluations, beliefs and intentions, the effect of history will primarily be checked by comparing changes as measured by the pretest posttest questionnaires with interview data. Changes in behaviour are in principle observable by the gatekeeper and other participants in a group model building project. As discussed above, we can expect a number of biases to operate in assessing one's own behaviour. Therefore, in order to determine whether changes in behaviour occurred after the group model building intervention, opinions of different participants will be confronted with each other

and with other available data (observations and documents). Observing behavioural change immediately after the intervention is still not sufficient to conclude that modelling is the source of these changes, but data on changes in evaluations and intentions can increase the confidence in outcomes found.
A second potential weakness of the one group pretest posttest design is regression to the mean. Since this study is concerned with stakeholders' evaluations on elements of a pressing organisational problem (Eden, 1992a: 8) we can expect to find extreme scores in the sense that some behaviours will be evaluated very positively and some very negatively. However, the appropriate population to compare scores against are managers involved in a messy problem. Stakeholders can be expected to have idiosyncratic and sometimes extreme ideas on which actions are desirable. In this sense extreme evaluation scores do not represent extreme scores for the population. However, extreme pretest scores can influence the effects found by limiting potential changes between pretest and posttest. This effect will be attended to by checking against possible ceiling and floor effects. In addition, it will be checked whether measured changes are due to extreme pretest scores. The question then becomes how to check that posttest scores are realistic and do not merely represent a regression effect. Assessing posttest scores in multiple ways is a possible remedy here.
The third threat, maturation, could threaten the results found if e.g. gains in experience would lead to changes in evaluations. In complex issues such as these, in which participants have been involved for a long time, the effect of additional gains in experience over and above the intervention is not very plausible. Using multiple ways to check how changes in evaluations came about, provides a check for the effect of maturation as well.
The fourth threat to validity, the testing effect, can be expected if being exposed to one test changes performance on another test. The intervention in this study is used explicitly because of its presumed effects on learning. Respondents might therefore deduce that changes in evaluations are expected, and be prone to answer posttest questions in line with this expectation. This again underlines the need to use multiple sources for gathering data on posttest scores.
The last threat mentioned by Cook and Campbell is instrumentation, which follows from a change in measurement of variables in the pretest compared to the posttest. For this study, this calls for an identical measurement of evaluations at two points in time.

In conclusion, Cook and Campbell (1979) describe a number of threats to a valid measurement of variables and (reasons for) changes in variables. Many threats to validity can be avoided by using multiple ways to assess evaluations, beliefs, intentions and actions. For evaluations, beliefs and intentions, a comparison of questionnaire and interview data will be used to this end. In the interview the reason for the change in variables will be addressed. This is discussed again in section 5.4.3 on the operationalisation of outcomes. Behavioural changes are assessed using interview data, observations and documents. Conclusions on the relation between modelling and behavioural changes will be substantiated by confronting changes in actions with changes in evaluations and intentions.

## 5.4 Operationalisation

The hypotheses described in section 5.2 focus to a large extent on variables in Ajzen's (1991) theory of planned behaviour. From the previous chapter it appears that this theory describes the antecedent variables that determine behaviour, but does not specify which behaviour in a complex domain should be focused on. The idea that behaviours and goals are organised in a hierarchy, with goals at a higher level influencing more specific goals and behaviours, is not included in the model. The theory of planned behaviour is instrumental in defining which cognitive and affective variables are important once a specific behaviour is identified. This leads to four considerations that are addressed before turning to the operationalisation of specific variables: identification of actions, estimation of the persuasive content of communication, time aspects of measurement and compatibility of measurements.

### 5.4.1 General considerations

*Identification of actions*

The first important point concerns the identification of actions. Since this study is concerned with actions of stakeholders in a messy problem, deciding on which action will be influenced is not a straightforward matter. Lane's observation (1992: 74), that group model building changes participants' goals by showing them how their goals fit in with the context of the whole system, makes it clear that modelling can have unanticipated effects. When participants refine their mental models over the course of a project, the focus of the model shifts and other issues, not considered important before, come to the fore. At the start of a group modelling building project, the problem to be addressed is typically only indicated in the form of a research question, for instance 'Which factors are responsible for the declining size of the Dutch merchant fleet?' (Vennix, 1995). The central issue for the present study is then how to identify relevant behavioural choices for specific participants on the basis of a very general idea on the goal of the modelling project. A further complicating factor is that the group of participants is heterogeneous because it is deliberately composed in such a way that all perspectives on a problem are represented. In Vennix' (1995) study, this means that representatives of three strategic areas are present in the sessions: the Dutch merchant fleet, the Dutch ports and sea traffic at the North Sea.

The model in this project shows the importance of the merchant fleet for the Dutch economy, which means that an overarching goal has been identified. In this study it is possible to identify a behavioural option which is relevant to all of the participants, since all participants jointly have to decide on whether or not to issue a request for subsidies to the Dutch government. It is important to note that the consequences of a decline in the size of the merchant fleet turn out to be the main insights in this case, while the project focus initially was on causes of the decline. It turns out that the strategic areas are interlocked to such an extent that a common goal is identified. In addition, participants share the responsibility for one of the main interventions in the problem. This is a far from common outcome. From the meta-analysis of group model building studies discussed in the second chapter, it appears that most cases resemble the health care study described by Vennix (1996). Here participants are general practitioners, medical specialists, policy makers and researchers in the health care field. Each of these subgroups has their specific expertise and is responsible for different decisions in the health care system. Since this group is far more heterogeneous, the identification of behavioural choices that are relevant to all of the participants is far more difficult. The results of this second study are therefore more on the conceptual level (the problem is redefined), while actions that are identified do not directly concern the participants but relate to initiation of further empirical research in health care processes.

These two examples show the difficulties of identifying relevant behavioural choices in advance of the modelling project and of discovering a shared action, particularly when participants form a heterogeneous group (see also Vennix, 1996: 201). In the present study a combination of procedures is used to identify relevant actions. For each case the problem is discussed with the gatekeeper, and an attempt is made to identify relevant actions for each of the stakeholders. Preferably an action is identified that is relevant to all participants. In fact this boils down to discovering possible actions deductively. In several cases a comprehensive description of actions turned out to be impossible to achieve. Not surprisingly, these are the cases with the most heterogeneous groups and problems high in social complexity. In these instances participants where asked to first identify possible actions, and in a second stage fill out the questions on the variables in Ajzen's theory for each of these actions[26]. This is done for all behavioural options in case 1 and 3, and three out of four options in case 2. In all other instances (one option in case 2, three options in case 4 and three options in case 5) relevant actions could be identified beforehand,

[26] In the first two cases the posttest included a question on the desired situation and behavioural options to create this desired state. In principle participants could add options not mentioned in the pretest, but almost no new options were mentioned.

and respondents filled out the questions with regard to these prespecified actions. Appendix E contains an overview of the actions.

*Persuasive content*

A second consideration is whether arguments will have a positive or negative influence on the variables in the theory of planned action. As might be clear from the discussion so far, it is difficult to define a preferred outcome before the intervention has taken place. The question can be raised whether alignment in itself is a good enough result of modelling, without considering the content of the outcome. Huz (1999: 138) raises the question which operationalisation of alignment is preferable: one which refers only to a decline in variability among individuals, or one in which a value is placed on what individuals align around? In the latter case alignment is considered movement toward a desirable perspective. The latter definition avoids the problem that alignment around negative actions would be considered a good outcome of the intervention. Taking into consideration whether alignment around the 'right' understanding has been created seems valuable, but leads to the further question of how to define the preferred direction of change. The character of messy problems makes it impossible to define any preferred outcome of the intervention beforehand. Since stakeholders have their own idiosyncratic views on the problem and shared understanding is lacking, there is no way to identify a solution beforehand that is any more specific than ideas such as 'stakeholders need to cooperate'. The objective of the intervention is exactly to find out what the preferred direction of change is. Only after the modelling sessions when project conclusions are captured in a report, can the arguments that were generated be identified. In this study I will therefore assume that the conclusions of the intervention reflect the preferred direction of change, and try to assess whether participants change their evaluations in the direction of these conclusions. The primary source for specifying conclusions is the model constructed in the intervention and the project report that summarises the main important insights gained in the process of model construction and analysis. More detailed conclusions can be found in the specific communications participants exchange during sessions. A comprehensive scan of the information exchanged in the modelling project would include the verbal communication during the sessions and the information contained in the different versions of the model, the workbooks and report. In this study I will limit the identification of arguments to the report concluding the study, which includes the final model and the project's strategic recommendations.

*Time aspects*

A third consideration is on time aspects, related to both the time required for the evaluation and the appropriate time for the posttest measurement. Since the research subjects are managers who according to Eden (1992a) are notoriously unwilling to participate in evaluations, pretest and posttest measurements will need to be kept as short as possible. In addition to a large number of variables per behavioural option, process elements will be assessed as well. A balance therefore needs to be found between the number of indicators per variable and the total time required of research subjects. In the section on variable construction a selection of indicators for each variable will be made.

In addition, given managers' limited time, measurement at more than two points in time needs to be avoided. For the posttest this brings up a dilemma between immediate measurement in order to capture changes in insights, or measuring after a certain time interval to provide managers with an opportunity to implement actions. In order to capture the changes in participants' beliefs, evaluations or intentions occurring during group model building, it seems best to conduct a posttest as soon as possible after the ending of the project. However, even if asked after a short time interval, self-reports on behaviours can not be expected to be fully accurate. Ajzen and Fishbein (1980: 37) consider self-reports of behaviour generally accurate, but reject their use if there is reason to suspect the accuracy of self-reports for a particular behavioural domain. In section 5.2 a number of possible biases in self-reports were cited, e.g. face saving operations. Measurement at a later point in time introduces an additional bias but also increases the likelihood that conclusions are implemented. The longer the time interval after the intervention, the greater the likelihood that other events occur that change opinions (Ajzen and Fishbein, 1980: 47). However, the review of group model building projects in chapter three indicates that in many cases, behavioural changes or implementation of project conclusions requires some time. For example a recommended change in personnel or production policy will not be implemented immediately.

From these considerations it seems therefore that testing participants immediately after the intervention is preferable. In the posttest interviews, participants will be asked to report changes with regard to the behavioural options identified in the questionnaires. As it seems difficult to determine which behavioural domains will be affected by the modelling project, an open ended question is included in the interviews as well. Participants will be asked which conclusions they have drawn from the group model building project, and whether or not they are behaving in a different way with regard to the problem or intend to do so in the future. Self-reports will need to be compared to estimations of behavioural changes by the project gatekeeper or inferred from documents. These measurements can be taken at a later (third) point in time, so that implementation of conclusions can be assessed as well.

*Compatibility of measurements on evaluations, intentions and behaviour*

In section 4.4 the idea of a hierarchy in behavioural goals was introduced. This is closely related to the compatibility principle as proposed by Fishbein and Ajzen (1975; Ajzen and Fishbein, 1980). According to Eagly and Chaiken (1993: 164) this principle states that evaluations, intentions and behaviours need to be formulated at a comparable level of aggregation in order to ensure a substantial correlation. Ajzen and Fishbein (1980) refine the concept of compatibility by breaking it down into four elements. They argue that every evaluation, intention and behaviour refers to a specific action, target, context and time. Compatibility between the variables in the theory of planned behaviour should be evaluated in relation to all four elements. Action refers to the single or multiple acts by the respondent or another actor. The target is the entity toward which an action is directed. In the example of 'increase competition between access providers', access providers are the target. The context generally includes the location or social situation in which a behaviour is performed. Time is specified by indicating a particular period in which a behaviour was or will be performed.

In the pretest employed in this study, the problem to be addressed in the group model building project is first defined. Subjects are then asked to define the desired situation they would like to see created in a particular time period. Subsequently they are asked to indicate actions that could be undertaken in that time period which would help in creating the desired situation. In the remainder of the pretest all questions on intentions and evaluations refer to the actions identified. In the posttest a similar format is used. This hopefully results in making the same target (desired situation), context (the problem setting) and time salient for actions, intentions and evaluations. Section 5.5.2 provides further details on how the variables in the theory of planned behaviour are measured.

### 5.4.2 Persuasive content

As discussed previously, group model building provides numerous occasions for a participant to receive information: from model structure and behaviour addressed in sessions, from other participants comments during discussions in the sessions, and from arguments captured in workbooks and the project report. All of these sources can be expected to have an impact on participants' evaluations of actions in the problem under discussion. In principle there are two ways to assess the impact of information in the sessions on participants' evaluations. The first option is to analyse the content of the information sources and arrive at the persuasive content as interpreted by the researcher. The second option is to ask the respondent's opinion on whether information on a particular behavioural option was generated, and whether this information was positive or negative. Both approaches will be used in this study.

*Estimation of persuasive content on the basis of content analysis*

Participants in a modelling session receive information from a number of sources: the model, other participants, the workbooks and the project report. For the purpose of simplification, in this study I will only consider the model and the project report for determining the persuasive content of arguments exchanged in modelling. The assumption is that the essence of communication during the sessions and the information in the workbooks, is captured in the model and project report.

Vennix (1990: 108) points out that a simulation model generates three different kinds of information about the system under study, i.e. information about the structure of the system, the dynamic characteristics of the system and the relationship between structure and dynamics. Since the intervention in this study includes qualitative as well as quantitative system dynamic models, we need to be careful in making specific assumptions about the relation between structure and behaviour. The relative merits of types of models have been discussed before. Richardson (2001) relates the ability of both model types to create insights to their purpose. From a qualitative model, it is generally possible to deduce the impact of changes in a steering variable on general patterns of model behaviour, for instance growth or decline of a dependent variable. Once a variable is locked into more feedbackloops this becomes progressively more difficult. Assessment of specific impacts, for instance the size or time path of changes, requires quantification of a model. For this study I will assume that it is possible to determine broad effects of a change in a steering variable on the basis of both the qualitative and quantitative models constructed in the cases. This assumption is backed up by the fact that expected outcomes of interventions in the model are discussed with the participant group and included in the project report. Vennix (1990: 109) notes that relationships between variables in a model contain at least four characteristics:

- sign (positive, negative);
- strength (or: magnitude, value);
- delays (kind of delay, length of delay);
- form (linear, non linear etc.)

In a qualitative system dynamics model relationships are generally described by their sign and whether or not they are delayed. In this study I will mainly use these two characteristics, sign and presence of a delay, to assess impacts on the dependent variable. If more specific expectations on effects of interventions in the model are provided by quantitative simulations or in the policy recommendations in the project report, these will be used as well.

In general I am concerned with the impact of information gathered during group model building on three variables: attitude towards action, subjective norm and perceived behavioural control. According to the theory of planned behaviour, any factor influencing intentions and behaviours will take effect through changes in one or more of these three evaluations. The expectation is that if through modelling new positive outcomes of an action are identified, the attitude towards this action will become more positive. Alternatively if previously unknown negative consequences of an action are discovered, the attitude towards action is expected to change in a negative direction. In effect this constitutes a change in a participants' ends model (for instance Huz, 1999). Subjective norm will change if a participant discovers new beliefs of important referents. I will make two simplifying assumptions here. The first is that the model represents the consensus view of participants in group model building. The second assumption is that for each participant, other members of the participant group are important referents. In this case the expected impact on attitude and subjective norm are similar: the identification of new consequences of an action will change behavioural beliefs and if it is believed that important referents agree to these consequences of the behaviour, normative beliefs are changed as well. In other words: following these assumptions, a model is expected to lead to changes of attitude and subjective norm in a comparable direction. Perceived behavioural control can be expected to change if previously unknown barriers or means to implementing an action are identified.

In order to make the estimation of expected changes as explicit as possible, it is useful to lay this out in a series of steps. These steps boil down to comparing the model and the recommendations contained in the policy report with the actions formulated by the participants in the project. On the basis of an analysis of the reports and models of the first two cases in this study (safety in a city district and Ministry of Transport) it was concluded that actions can first be categorised as either referring to a *form* of decision making or express a preference on the *content* of a decision. An example of the former is an action identified by a participant in the second case, where each participant comes from a different department within the Directorate General of Telecommunications and Post. One participant identifies the action: 'to give more attention to own department's key tasks'. Since in this case each participant represented his or her own department, the action implies that more attention is devoted to subgoals than to overarching goals on a higher organisational level. This can be contrasted with another action in the second case: 'to give more attention to consultation with other members of the Directorate General'. These two actions constitute the extremes of a dimension of goals considered important in the decision making process: goals of one's own specific department versus goals at the level of the organisation as a whole. It seems clear that system dynamics generally

favours a more integrated perspective and higher level goals. This is illustrated by Vennix (1995) where the overarching goal, that is important to all of the three conflicting parties, serves to overcome a 'departmental bias'.
In addition to the form of the decision, the content of the decision is important as well. With regard to the content of a decision the ideas of the previous paragraph can be followed in a quite straightforward manner: identification of new positive outcomes will tend to make a participant's attitude more positive, while identification of new ways to influence a variable will tend to increase perceived behavioural control. Keeping in mind the simplifying assumptions above, identification of new positive outcomes will tend to make the subjective norm more positive as well. If negative outcomes are identified, attitude and subjective norm are expected to change in a negative direction.
For perceived behavioural control it is not the outcome of an action that is important, but the extent to which an actor can influence the variable. If the actor discovers to have more (or less) influence over a variable than expected, perceived behavioural control is expected to increase (or diminish). In general a variable under control of the actor is identified as a steering variable, either by indicating in the model which organisational department is responsible for which section of the model or by indicating preferred changes in the report's recommendations. If a variable is explicitly included in the project recommendations as a steering variable, perceived control is expected to increase. If a variable is not included in the project's recommendations, but can be found in the model, deducing the expected direction of change is not as straightforward. As explained above, I assume that the dynamic behaviour resulting from the proposed interventions in the model can be deduced on the basis of the (qualitative as well as quantitative) model. If these interventions impact a variable positively, this is assumed to increase control over a variable. In other words, on the basis of the recommendations of a study, the direction of change of endogenous variables in a model can be estimated. If this change is in the same direction as a participant's action and thereby supports it, I assume that perceived control over this action is increased. In the second case, for instance, a participant identifies the action 'increase competition between access providers'. The actions identified in the project report, directly and through other variables in the model, work to increase the competition between providers. Perceived control over increasing competition is therefore expected to grow.
A final possibility is that the action is specific to the participant's department and is not discussed in the sessions. In that case neither the model nor the recommendations will contain a variable that can be linked to the action.

The following table summarises the steps in determining the impact of the model on evaluations of actions. Row 1 and 2 in the table refer to the form of the decision, either focussing on overarching goals (row 1) or on subgoals important to a specific department (row 2). Rows 3 to 10 refer to the content of actions: whether actions have positive or negative consequences, and whether actions are within the control or not under control of an actor. The final row (11) refers to actions that can not be linked to outcomes or control of an actor.

| *Relation between action and model or recommendations* | *A* | *SN* | *PBC* |
|---|---|---|---|
| 1. An action refers to cooperation or consultation of the different organisational departments present in the project | + | + | + |
| 2. An action refers to goals or tasks of a specific department present in the project | - | - | - |
| 3. A recommendation indicates that a corresponding action is within the control of the actor and has positive outcomes | + | + | + |
| 4. A recommendation indicates that a corresponding action is within the control of the actor and has negative outcomes | - | - | + |
| 5. A recommendation indicates that a corresponding action is not under control of the actor and has positive outcomes | + | + | - |
| 6. A recommendation indicates that a corresponding action is not under control of the actor and has negative outcomes | - | - | - |
| 7. An action corresponds to change in a variable included in the model in the same direction as expected model behaviour, and has positive consequences | + | + | + |
| 8. An action corresponds to change in a variable included in the model in the same direction as expected model behaviour, and has negative consequences | - | - | + |
| 9. An action corresponds to change in a variable included in the model contrary to the direction of expected model behaviour, and has positive consequences | + | + | - |
| 10. An action corresponds to change in a variable included in the model contrary to the direction of expected model behaviour, and has negative consequences | - | - | - |
| 11. An action does not correspond to a recommendation or a model variable | | | |

Table 5.1 *Steps in determining the expected direction of evaluation change, with* A *indicating attitude towards action;* SN *subjective norm;* PBC *perceived behavioural control. If a cell is left blank, expected direction of change cannot be estimated. A positive influence is indicated by '+' and a negative impact by '-'.*

In the above the correspondence between model variables and the actions identified by participants was treated as unproblematic. As the study by Vennix (1990) clearly shows, this is seldom true. Vennix asks respondents to write a policy note, indicating how the Dutch social security system should be changed in such a way that it optimally benefits from economic developments. Subjects are then asked to participate in a gaming simulation or a control condition, after which they again write a policy note. Vennix (1990: 119) develops an elaborate procedure for linking model concepts to concepts used in the policy notes. The correspondence of a policy note concept to a model concept is not straightforward, as a policy note concept is generally less precise than a model concept and can relate to more than one model concept. In Vennix' study, the translation is performed by different coders that each receive elaborate training on the coding procedure. The translation in the present study is less complicated, as I am not concerned with the correspondence of a complete policy note to a model, but only with the correspondence of specific actions to variables in a model. However, since estimation of expected changes in attitudes, norms and control is crucial to this study's outcome, an explicit procedure to be employed by several coders seems useful.

The steps in the table are based upon another simplification, which has been discussed in previous chapters. It is assumed that a coder is able to estimate the impact of the model and project report on individual evaluations unequivocally. For instance I assume that the arguments contained in the model are new to all participants, while they have been brought forward in the sessions by one of the participants. Elements of the model might therefore be new to some participants, while others are already familiar with them and therefore do not change their evaluations. In addition, Scheper's (1991) communication model indicates that a participant's complete mental model might be brought to bear upon any of the concepts contained in the model or project report. A participant's interpretation might therefore be highly idiosyncratic and cannot easily be guessed by an outside observer (i.e. coder). However, as shown in section 5.3, participant's recollections might be biased and an assessment procedure taking into consideration individual interpretations asks for a (too) large time investment on the side of subjects. For these reasons, the participant's ideas on how a project impacted his evaluations will be assessed after the intervention, and compared to the pretest and posttest scores. The following section describes the procedure for obtaining participants' estimation of the impact of information received in the modelling sessions.

*Estimation of persuasive content by respondents*

The second option for assessing whether participants received positive or negative information on a particular behavioural option, draws on participants' subjective estimation of the impact of information exchanged during modelling. To this end, participants are confronted with their answers on the pretest and posttest questionnaires and asked to reflect on changes between the two. This procedure has the potential to provide valuable additional information, since we expected an unequivocal estimation (by an outsider) of the effect of the intervention on participants' evaluations to be difficult. Self-reflection provides more detail on how information was taken up by a participant. However, the procedure runs many of the risks of retrospective self-reports described in section 5.3 on design. Information might be biased, e.g. by face saving operations. In the interviews after the intervention, the following steps were taken to avoid biased answers as much as possible.

1. Early on in the interview, participants were asked whether the sessions or workbooks provided information relevant to their work.
2. Secondly, participants were shown the scores on pretest and posttest questionnaires, and asked to which extent differences between the two were recognisable. Answers to this question can go in two directions. In one extreme, scores on the questionnaires are not recognisable for which a number of factors can be responsible (e.g. a change in interpretation of questions, boredom with filling out the tests). The opposite extreme occurs when a participant agrees the change in questionnaire scores represent a shift in evaluations. In the former extreme, where the respondent does not recognise a change, the validity of measurement by using a pretest and posttest is questioned. In this case a conclusion about shifts in evaluations is impossible to draw. In the latter case, where the respondent agrees to the shift in evaluations measured in the questionnaires, confidence in the results is increased.
3. Only if the respondent recognised and agreed to the evaluation change, the third topic was addressed. The third question pertains to the reasons for evaluation change. The participant was asked to indicate whether information received during the intervention, or factors outside of the intervention were responsible for a change in evaluation. Again, if the participant credited the modelling process for the information, this gives more confidence in the capability of group model building to provide arguments on the basis of which evaluations are changed. The increasing focus provided by the three steps hopefully helps to limit self-presentational concerns.

The three questions provide both a check on the evaluation change as estimated by the questionnaires as well as a check for the reason of an observed change. Therefore the data with regard to these questions are also relevant to the hypothesis on argument quality, and are discussed more fully in that section.

### 5.4.3 Outcomes: theory of planned behaviour

The variables in the theory of planned behaviour will be measured both before and after the group model building intervention. To avoid the threat of instrumentation (Cook and Campbell, 1979), variables will need to be operationalised and measured in a comparable way at both points in time. The variables in the theory of planned behaviour are generally measured using a questionnaire (Ajzen, 1991; Eagly and Chaiken, 1993). In order to ensure identical measurements in pretest and posttest and to measure variables in a way comparable to other application domains, I will follow this practice for all variables with the exception of behaviour. To keep the questionnaire brief the number of items will be constrained as much as possible. The formulation of each item is chosen in such a way that questions can apply to different behaviours and problem domains, since I want to ensure identical measurements over respondents in one case as well as over cases.

*Behavioural, normative and control beliefs*

Section 4.3.2 described the cognitive foundation of evaluations, as captured by the Ajzen and Fishbein (1975) model. Ajzen (1991: 189) points out that the theory of planned behaviour postulates that behaviour is a function of salient beliefs. Three categories of salient beliefs are distinguished: behavioural beliefs that influence attitudes towards actions, normative beliefs that underlie subjective norms, and control beliefs that constitute the basis for perception of control. Beliefs were measured in three steps[27].

1. First, important attributes, i.e. outcomes, referents and threats or opportunities, were identified. An example of a behavioural outcome is 'a better qualified workforce'. The number of attributes ranged from three to seven depending on the time participants had available for the evaluation. In cases 1 and 3 respondents defined beliefs themselves, while in the other cases salient beliefs were identified on the basis of interviews with the project gatekeeper and a small number of participants. In case 1 the primary reason for asking participants to identify beliefs instead of specifying these beforehand, is that the group of participants was very heterogeneous. The group included among others a police officer, managers of housing associations, and managers of different city administration departments. In this case it was thought impossible to identify beliefs that were relevant to all participants. In case 3 the reason for asking respondents to identify beliefs themselves was that the time for preliminary interviews in which relevant beliefs could be identified, was lacking. In addition, since in this case only two actions and two beliefs for each attribute category (outcomes, referents and threats or opportunities) were included in the questionnaire, it was not expected that the use of an open question on beliefs would be too time consuming for participants.

[27] The first case is again different in this respect, as pretest and posttest beliefs were not necessarily similar. In the posttest respondents were again asked to identify relevant beliefs, Which could be different from the ones mentioned in the pretest. About 46% of the beliefs in the posttest are new.

2. In the second step the evaluation of each outcome was assessed, for instance how important a specific behavioural outcome would be. This could be scored on a scale from 1 (very unimportant) to 5 (very important).
3. In the third step the strength of the relation between behaviour and attribute, or belief strength, was measured. An example of a question measuring the strength of the relation between behaviour and outcome is shown in figure 5.2 below. Before answering this question, respondents have already identified behavioural options, outcomes (e.g. a better qualified workforce) and the evaluation of the outcome (very important to very unimportant).

*Indicate to which extent the behavioural options (indicated on the previous page) contribute to the consequences identified above. Please indicate your answer on a scale from –5 to +5, in which:*

*-5 = is very harmful to this consequence;*
*0 = is not harmful, but not beneficial to this consequence either;*
*+5 = is very beneficial to this consequence.*

*For example, if you fill out +5 after consequence 1 in the first column (see the following table), you indicate that you expect option 1 to contribute very strongly to consequence 1.*

| | Option 1 | Option 2 | Option 3 |
|---|---|---|---|
| Consequence 1 | | | |
| Consequence 2 | | | |
| Consequence 3 | | | |

*Figure 5.2 Sample of questionnaire item on behavioural beliefs*

As stated in section 5.4.3, Fishbein and Ajzen (1975) propose to multiply belief strength and evaluations over all beliefs to obtain a measure of behavioural, normative or control beliefs. The construction of belief scores on the basis of these scales for belief strength and evaluation is described in the following section on variable construction.
For normative beliefs open ended questions were asked in the posttest questionnaire and in the interview, in addition to the closed format questions described above.

*Attitude towards behaviour, subjective norm and perceived behavioural control*
Attitude towards behaviour is usually measured using a semantic differential (Ajzen and Fishbein, 1980; Ajzen, 1991; Cordano and Frieze, 2000) and this approach is used here as well. For operationalising subjective norm, I used the format proposed by

Ajzen and Fishbein (1980: 57). This format assesses a person's perception of the general social norm on performing or not performing a behaviour. The operationalisation of perceived behavioural control builds on the scales employed by Madden et al. (1992) and Hill et al. (1996).
As indicated in the previous section, participants were asked in the interviews whether they recognised changes in evaluations estimated on the basis of the questionnaires. In all interviews participants answered this question positively, which increases the confidence in the validity of evaluation measurements.

*Intention and behaviour*
Madden et al. (1992: 6) provide a number of items for measuring intentions, of which a subset is used in this study.
As indicated in section 5.4.1, behavioural options are either identified by the respondent (in case 1 two options; in case 2 and 3 three options) or specified by the researcher (in case 2 one option; in case 4 and 5 three options). Additional options are identified in the interview.

### 5.4.4 Mechanism: arguments

In this section the first element of the mechanism operating in group modelling is addressed: the quality of arguments that are exchanged over the course of the intervention. The quality of the process is the topic of the following section. Process quality and content quality are difficult to disentangle and it seems reasonable to expect a relation between both. Vennix (1996) cites several studies in which process characteristics such as communication openness are found to be related to exchanged arguments and the quality of the resulting decision. However, McCartt and Rohrbaugh (1989: 245) warn us that the quality of a decision depends on factors outside of the decision process leading up to it. The process of deciding to invest in a new technology can be of high quality, but it can fail to predict the actual return on investment due to events after the decision process. Process and content quality therefore need to be considered separately, and in a field setting the process cannot be evaluated on the basis of content or outcomes alone (McCartt and Rohrbaugh, 1989).

In order for pieces of information exchanged in a modelling session to become arguments capable of changing evaluations, they 'should either constitute some of the primary beliefs underlying the behaviour, or they should be known to determine or influence those primary beliefs' (Fishbein et al., 1980 : 227). As mentioned in section 4.4 arguments are new facts that are relevant to a particular action (Eagly and Chaiken, 1993: 309; Petty and Cacioppo, 1986). In other words, a strong argument has a clear relation to an important belief. In case of a weak argument, the related belief is either not important or the relation is unclear. This characterisation of arguments bears a strong resemblance to the concept of decision quality that is more common in the literature on group decision support. Decision quality refers to the degree to which an advocated action is supported by factual evidence. Both argument quality and decision quality refer to the weighing of negative and positive consequences of an action.

In determining the quality of arguments in a group modelling session, first of all it is important to realise that the messy problems addressed in these sessions by definition do not have one best answer or solution. In group model building we are not concerned with an intellective task which has one best answer. Instead we are dealing with a judgemental task for which no optimal solution is available (Zigurs, 1993: 118). Identifying the value of an argument in a specific case is therefore difficult. Janis and Mann (1977) point out that for decisions in field settings, an objective estimation of positive and negative consequences is all but impossible. This would boil down to evaluating the extent to which the objectives of the decision are realised and which undesired losses are obtained. But as Janis and Mann (1977: 10) note:

> *'Since there is no way of obtaining quantitative scores for these values, one would have to ask decision makers to give subjective ratings of the degree of their postdecisional satisfaction and regret.'*

These ratings are prone to a number of decision making errors, such as face-saving and rationalisations, especially if participants rate their own decision. In addition, the quality of a decision has to be established after all its effects had their impact, or else boils down to projecting losses and gains in the future. Zigurs (1993) notes that researchers in the field of US GDSS often assess decision quality on the basis of participants' estimations. In effect this means that decision quality is defined as perceived quality, which is easily confounded with perceived satisfaction.

Alternatively, perceived decision quality might be assessed by outsiders who did not participate in making the decision. Outcome quality of GDSS processes is often judged by outside experts (e.g. Kenis, 1995: 152; Hart, 1985: 210). This procedure has several drawbacks in the case of group model building. In group model building the aim is to bring stakeholders that are experts on the problem together, and combine and structure their knowledge in a model. A rating of recommendations arrived at in group modelling by a second group of experts might also suffer from a number of biases. First, since problems are highly specific, the second group might come up with different recommendations because their backgrounds are different than the modelling group. Second, a creative solution identified through modelling might be rejected by outside experts, because they did not participate in the discussion leading up to it and were not able to take part in the argumentation process themselves. A rating of decision quality by outside experts is therefore problematic.

Two other descriptions of arguments exchanged in decision making are Toulmin's logic (Toulmin, 1958) and Dunn's categorisation of policy making phases (Dunn, 1994). Both descriptions are primarily analytical and have little to offer in deciding on the relative quality of arguments. In contrast, Janis and Mann (1977) describe procedural criteria for decision making that can be employed to assess quality of arguments. The more these criteria are satisfied while making a decision, the less likely the decision maker is to 'undergo unanticipated setbacks and experience postdecisional regret' (Janis and Mann, 1977: 11). Although Janis and Mann see their criteria as characteristics of vigilant information processing, which closely resembles process quality, reformulating the criteria to address quality of the resulting decision is relatively straightforward. The main difference between Janis and Mann's procedural criteria and process measurements, is that the latter deals with characteristics such as openness, focus and clarity, while the former explicitly specifies the content of a decision. The procedural criteria specify that in order to arrive at a high quality decision, e.g. all alternative courses of actions and all objectives should be addressed. Janis and Mann's criteria have a clear relation to the approaches by Dunn (1994) and McCartt and Rohrbaugh (1989). The criteria correspond to Dunn's (1994) phases of decision making in the sense that causes and context of the problem are identified, options selected, outcomes identified and weighed and a satisfactory option is chosen on the basis of an integration of all available information. In the four dimensional model of McCartt and Rohrbaugh (1989), Janis and Mann can be situated primarily in the empirical and rational dimensions. These are concerned with whether the decision is based on empirical data and clear goals, respectively. The two other dimensions, the political and consensual perspective, are subsumed under process quality.

In sum, since the type of problems addressed in group modelling sessions do not have an optimal solution, and rating of the quality of arguments exchanged by both participants and outside experts is difficult, an alternative way is selected to assess quality of arguments exchanged in the meetings. A scale developed by Janis and Mann (1977) that addresses to which extent arguments are based on facts and rational considerations is used to this extent. This provides a way to identify strong arguments: information that has a clear relation to beliefs concerning e.g. actions and outcomes. Section 5.5.3 provides further details on the scale used for measuring argument quality.

### 5.4.5 Mechanism: process quality and intervention elements

*Process quality*

This section addresses the mechanism expected to set evaluation change in motion. In section 4.4 the two theoretical models that will be used to identify important variables in evaluation change were discussed: the Heuristic Systematic Model (HSM, Chaiken et al., 1989) and the Elaboration Likelihood Model (ELM, Petty and Cacioppo, 1986). These models specify two ways in which evaluations might change, by receiving information or by heuristics. The more a person is motivated and able to process, the more attention is paid to the information in the message. In section 4.4 I argued that in group model building participants will both be able and motivated to carefully consider all information that is being exchanged. Group model building primarily increases the ability to process information by structuring information using a model, and facilitating the communication process. A person's motivation to participate in the modelling process and to process information exchanged, is not directly influenced by the intervention. The importance of motivation is also recognised in the system dynamics literature, as can be seen from the following statement by Roberts (1978: 79):

> *'If you want to achieve changes in an organization as a result of your corporate modelling work, the problem or opportunity that you select must be important to the client. Otherwise, that client will neither pay much attention to the modelling effort, nor bother with its resulting recommendations.'*

I assumed that since participants are stakeholders in a messy problem, they will be motivated to pay attention to information on the problem. Motivation is not directly influenced in group model building but clearly important in shaping the outcomes of the intervention. It is thus a context factor and will need to be incorporated in an evaluation of modelling. Motivation will be considered in more detail in the following section.

The central mechanism element in this study is the ability to process information. In this section I will first address the operationalisation of ability in HSM and ELM. Both models do not provide much help in providing a conceptual definition, as they primarily rely on empirical measurements of ability. However, the variables employed to manipulate ability provide insights into the relevant dimensions of ability to process information. Since these are close to factors considered in GDSS research, a connection is made to operational definitions employed in these studies. The second topic are the elements of the intervention, which need to be evaluated in order to assess why different cases result in different outcomes. Last, the subjective comparison of the effects of group model building to traditional approaches is addressed.

Petty and Cacioppo (1986) operationalise both motivation and ability using an empirical method. A variable increasing motivation and/ or ability should enhance the extent to which a subject processes arguments, and result in more polarised attitudes. They then go on to discuss specific variables that are found to influence either ability or motivation: distraction, repetition, personal relevance or involvement, personal responsibility, need for cognition, message comprehensibility and prior knowledge. In addition, several variables, e.g. initial attitude, will affect message processing in a biased manner. These will not be discussed here as I assume that the nature of processing will primarily be determined by the arguments in the messages exchanged during modelling. The HSM (Eagly and Chaiken, 1993: 328) also operationalises ability to process empirically: by varying time pressure and knowledge about the message topic, ability to process is expected to change. HSM's treatment of motivation is more elaborate and is addressed in section 5.4.6.

This section is primarily concerned with the question whether group model building creates the right setting to enable participants to process information. Since the modeller or facilitator does not address the content of communications, ability can be influenced by either affecting the environment or the format in which information is exchanged. Of the variables considered by ELM and HSM, this leaves distraction, repetition and message comprehensibility as the most important factors. Petty and Cacioppo (1986: 141) list several studies showing that the most important characteristic of distraction is that it disrupts thinking that would normally be elicited by a message. Repetition affects processing in two stages. Initially, contrary to distraction, repetition increases the ability to identify the arguments in a message. Once all implications have been assessed, a second stage begins in which increased repetition leads to boredom. Message comprehensibility works in much the same way as distraction: low message comprehensibility draws attention away from the implications of the message.

The four dimensional framework defined by McCartt and Rohrbaugh (1989) clarifies which factors might operate as distractions and lead participants to turn their attention away from the content of communications. The degree to which the decision process is focused on data and rationality, were covered by the first two dimensions and closely resemble content quality. This was discussed in the previous section. The political and consensual dimensions constitute the other two perspectives on decision making. These are concerned with the extent to which the process is adaptable to the group's needs and all participants are encouraged to participate. The relation to distraction can be illustrated as follows. If we assume a participant feels the discussion somehow avoids the most important issue, he will be distracted from the information exchanged at that moment. If he is not encouraged to participate in the discussion and ask for clarification if e.g. model concepts are

unclear, message comprehensibility will be lowered. On the other hand, if a message is understood and all implications are clear, further repetition will lead to boredom. According to McCartt and Rohrbaugh, all four perspectives are important and need to be attended to in decision making. The description of distraction makes it clear that the political and consensual dimension have to be sufficiently heeded to in order to ensure attention to message content. This brings us back to the dual goal of group model building summarised in table 2.4: the modeller or facilitator needs to balance attention to group needs (cohesion and equal participation) and quality of communication.
In this study I decided to employ a scale on process aspects, covering possible sources of distraction, incomprehensibility, and repetition. This scale consists of eight items covering different process elements, e.g. clarity of communications and attention to each other's ideas. Several items in this scale have been adapted from questionnaires used by McCartt and Rohrbaugh (1989) and Vennix et al. (1993). The resulting scale was first used in a study by Rouwette et al. (1997). In addition, two more general items were included on overall efficiency and success of the modelling project.

The second part of the hypothesis on process quality was concerned with the subjective comparison to a control group. For this comparison I used a scale developed by Vennix et al. (1993). This scale consists of seven items. Subjects are asked to compare group model building to regular meetings with regard to e.g. quality of communication.

*Intervention elements*
The final element of process quality concerns the elements of the intervention. Group model building consists of several components that each might have a different impact on participants' evaluations. The question of which elements of the intervention are particularly effective, links to the debates in the system dynamics field on the place of qualitative models and appropriate size of models (see chapter two). Several authors (McCartt and Rohrbaugh, 1989; Vennix et al., 1993) discuss elements of group decision support systems at an even more specific level, for instance the location of the sessions away from the office or the formal structuring of the sessions. In their evaluations of modelling, Vennix (1990) and Verburgh (1994) take into consideration factors such as time investment for participants and evaluation of specific sessions. In order to be able to compare different projects to one another, it is useful to have information on which different components were used and how these were evaluated by participants. There are several indicators which can be gathered by the researcher:
- participant characteristics (number and function);

- name of consultant;
- duration: time involvement of participants and project duration;
- techniques employed in the intervention;
- model characteristics (model size, qualitative or quantitative model, use of a preliminary model).

These resemble the intervention characteristics included in the meta analysis of reports on group model building interventions (see section 3.2).
For the subjective evaluation of components by participants, I chose not to evaluate specific sessions as this would increase the time required for evaluation. Instead I employed a scale on the contribution of elements of the method. This scale is adapted from McCartt and Rohrbaugh (1989) as well, and has been used by Vennix et al. (1993) and Vennix and Rouwette (2000). The scale used in this study contains eight items that cover the main components modelling and facilitation, as well as others such as use of a group memory, and the opportunity for open and extended discussion.

### 5.4.6 Context: client and problem characteristics

Differences in outcomes of group model building interventions can arise from discrepancies between interventions (mechanism elements) or discrepancies in the context of the intervention. The main elements of the context of a modelling intervention are the problem and client characteristics. Problem characteristics that are important in shaping the intervention were described in section 2.4 on complex problems. Problems high in both social and analytical complexity were described as messy problems. I will use the elements described by Hickson (see table 2.3) as indicators for the complexity of the problem. In the following chapter, background and intervention of each case in this study will be described. In order to limit the amount of time required for evaluation from participants and the project gatekeeper, problem complexity will not be included in the questionnaires or interviews. For each case the scores on the above indicators will be described qualitatively, on the basis of document analysis.

The second type of contextual variables relates to client characteristics. In the persuasion theories used in this study, motivation to process information is the most important client characteristic. The HSM (Eagly and Chaiken, 1993: 330) describes the concept of motivation by relating it to the actual and desired degree of confidence in a judgement. The HSM is based on the assumption that people will be motivated to process information up to the point where they have reached a sufficient degree of confidence in their judgement. Variables in the persuasion context operate either to increase the sufficiency threshold (the desired degree of confidence) or decrease actual confidence. Petty and Cacioppo (1986) discuss three variables that influence motivation to process: personal relevance, need for cognition and personal responsibility. Eagly and Chaiken (1993: 332) expect a personally relevant message to motivate a recipient to process the information contained in the message because it increases the recipient's sufficiency threshold. Such a person desires a greater level of confidence in his judgement than someone who receives a less personally relevant message. Need for cognition and personal responsibility operate in a similar fashion: an increase in either variable increases the sufficiency threshold. Since participants in group model building are selected on the basis of their knowledge or responsibilities in the problem, we expect them to perceive both a high outcome relevance and personal responsibility. Need for cognition is an individual characteristic and not related to a participant's position with regard to the problem, and will not be considered in this study. Since relevance and responsibility are difficult to separate in an organisational context, I will subsume both under the umbrella term 'importance'. Relevance and responsibility are defined at an individual level, which means that we are interested in assessing the degree to which a participant feels the information exchanged during modelling is important to him or her *personally*. Since individual importance does not necessarily have to reflect importance to the organisation, the organisational and individual dimension are addressed separately. In addition, as the modelling project starts out with no more than a problem 'label' to go on, a subject's perception of importance might change as the problem is structured in the course of modelling. It is therefore useful to measure importance at two points in time. Two items in both the pretest and posttest questionnaires address the motivation to process information on the problem to modelled. The first concerns the importance of the problem to the subject's organisation. The second item is on the importance of the problem to the subject personally.

Three other individual client characteristics were included in the analysis: the extent to which participants could implement conclusions, their age and years working with the organisation. The first characteristic reflects the idea that in order to achieve implementation of recommendations, managers with decision making power rather than staff should be involved in the problem (Roberts, 1978). Weil (1980) describes early modelling projects where the emphasis was on the model, the modellers worked more or less independently of the client and interaction was mostly with staff people. The end product of the project generally was a report. Weil concludes that only in a few of these projects conclusions were implemented. In contrast, more recent modelling projects involved managers directly to ensure a direct transfer of insights and implementation. From an intervention perspective it is therefore important to consider the extent to which participants are able to implement recommendations. From an evaluation perspective this is important as well, as

Ajzen's (1991) theory postulates that perceived control has a direct influence on actions to the extent that it resembles actual control (see section 4.3.2). The last two individual client characteristics to consider are participant's age and years working with the organisation.

Finally, in keeping with the meta analysis of reports on group model building interventions (section 3.2), a number of characteristics of the client organisation were recorded as well. These include organisation sort (profit, non-profit or governmental), sector and size.

## 5.5 Variable construction

The first topic of this section is the coding procedure employed to arrive at the persuasive content of the arguments exchanged in modelling. The second topic is scale construction for the dependent and mechanism variables. For the dependent variables specified in Ajzen's (1991) theory, it is possible to draw on various studies in other domains. Two concerns are important here: the need to limit the length of questionnaires as much as possible, and the fact that different attitude targets will be addressed in the different cases. Mechanism elements, process quality and arguments were measured using a scale as well. Data from a previous study are employed to assess the factors in this scale. The third and last topic is the description of context, for which qualitative data on problem complexity are combined with posttest items on perceived problem importance. Appendix C includes the pretest and posttest questionnaires.

### 5.5.1 Persuasive content

Section 5.4.2 described the procedure for the persuasive content of the communication in the modelling project on the basis of the project report. The procedure was laid out in a series of steps, enabling different coders to determine expected changes. In this section the reliability of the coding procedure is addressed. Krippendorf (1980: 130) distinguishes stability, reproducibility and accuracy (see also Vennix, 1990: 146). Stability refers to changes in the coding process over time, and is also known as intracoder reliability or consistency. Reproducibility or intercoder reliability refers to the question whether the coding process is similar under varying conditions. A difference in conditions is introduced when e.g. different coders are used. Accuracy concerns the similarity of the results of the coding process to a particular standard. Usually the standard consists of an expert coding. According to Krippendorf the latter type, i.e. accuracy, is the strongest test of reliability. He considers intracoder reliability the weakest form of reliability. In the present study it was difficult to formulate a standard that encompassed all possible action alternatives. Instead, two researchers coded all actions following the procedure outlined in section 5.4.2. This led to an initial agreement on about 75% of the actions. For the remaining actions, differences in scoring were discussed and ultimately a category chosen. For a minority of actions, this included going back to the interview data to check the researchers' interpretation of the description of an action. In conclusion, categorisation of most actions is straightforward and after discussion agreement on all scores was obtained. Although this procedure does not employ an expert coding, results are reliable in the sense that arguments for choosing a category are presented and tested.

In addition, respondents were asked to assess whether the modelling sessions provided positive or negative information about behavioural options (see section 5.4.2). This issue was addressed in three steps, in which respondents were asked a. whether the sessions provided information relevant to their work, b. whether changes from pretest to posttest were recognisable, and c. whether these changes came about through information exchanged in the sessions or to other developments. The answers to these questions is discussed more fully in section 7.3.1 on outcomes with regard to argument quality. In short, answers to the first two questions point to a number of difficulties in self-assessment of changes in insight. Participants on one hand indicate they have not learned anything new in the modelling sessions, but on the other hand readily recognise and accept the changes in evaluations from pretest to posttest. The interviews indicate that group model building results in integration of information, and yields examples of problematic behaviour that participants were not familiar with. Only a small minority of observed changes is discussed with respondents, of which the larger part is contributed to information outside of the sessions (14 out of 19 observed evaluation changes). However, even if we except the impact of external information, this does not necessarily mean that information exchanged during modelling has no impact. It seems logical to expect both types of information to be influential. Observed evaluation change is likely to be the result of an integration of all information (and peripheral cues) participants are confronted with between pretest and posttest measurements.
In conclusion, it is difficult to judge the value of participants' estimation of the persuasive content of communication. In the following, the coding procedure based on the researcher's assessment of change categories will be used. In the last chapter alternative research strategies are discussed.

The following table shows the frequency of change categories.

| *Relation between action and model or recommendations* | *A* | *SN* | *PBC* | *Freq* | *Perc* |
|---|---|---|---|---|---|
| 1. An action refers to cooperation or consultation of the different organisational departments present in the project | + | + | + | 14 | 16.3% |
| 2. An action refers to goals or tasks of a specific department present in the project | - | - | - | 1 | 1.2% |
| 3. A recommendation indicates that a corresponding action is within the control of the actor and has positive outcomes | + | + | + | 51 | 59.3% |
| 4. A recommendation indicates that a corresponding action is within the control of the actor and has negative outcomes | - | - | + | 7 | 8.1% |
| 5. A recommendation indicates that a corresponding action is not under control of the actor and has positive outcomes | + | + | - | 6 | 7.0% |
| 6. A recommendation indicates that a corresponding action is not under control of the actor and has negative outcomes | - | - | - | 1 | 1.2% |
| 7. An action corresponds to change in a variable included in the model in the same direction as expected model behaviour, and has positive consequences | + | + | + | 1 | 1.2% |
| 8. An action corresponds to change in a variable included in the model in the same direction as expected model behaviour, and has negative consequences | - | - | + | 0 | 0% |
| 9. An action corresponds to change in a variable included in the model contrary to the direction of expected model behaviour, and has positive consequences | + | + | - | 0 | 0% |
| 10. An action corresponds to change in a variable included in the model contrary to the direction of expected model behaviour, and has negative consequences | - | - | - | 1 | 1.2% |
| 11. An action does not correspond to a recommendation or a model variable | | | | 4 | 4.7% |
| Positive | 72 | 72 | 73 | | |
| Negative | 10 | 10 | 9 | | |
| Neutral | 4 | 4 | 4 | | |
| n | 86 | 86 | 86 | | |

*Table 5.2 Frequency of change categories*

The last two columns in the table indicate how many of the total number of 86 actions fall into a specific category. Please recall that an action is placed in a particular category if two researchers agreed on its categorisation, as described before.

Table 5.2 shows two striking results: the large number of actions that are positively influenced, and the low number of actions that fall in the neutral category. For each of the Ajzen variables the number of positive influences is far larger than the number of negative influences. Group model building seems far more likely to result in positive than in negative arguments. About 60% of all actions fall in category three, indicating that participants are in control over the action and the action is expected to lead to positive outcomes. This result seems to correspond to intuitions, as project reports tend to focus on implementable changes to the problematic situation, and therefore put most emphasis on positive arguments.
Secondly, only four out of 86 actions do not correspond to a recommendation or model variable (category 11). This means that most of the actions that participants see as relevant to the problem, are addressed in the modelling sessions. Section 7.3.2 provides further detail on participants' evaluations of the process.
In conclusion, the data indicate that group model building results in relevant arguments with regard to participants' positions versus actions in the problem. These arguments are mostly positive. In the following section the changes in evaluation and cognitions due to these arguments is addressed.

On the basis of the persuasive content of exchanged arguments, variables (beliefs, evaluations and intentions) that received negative information and variables that received positive information are identified. In section 4.4 it was described that some evaluations receive negative information and are expected to change in a negative direction. If for instance during the modelling session an action is found to have negative consequences, the attitude towards this action is expected to become more negative. In the following, evaluations that are expected to change in a negative direction will be referred to as unsupported or unconfirmed evaluations, or evaluations receiving negative information. In a similar fashion, beliefs that receive positive information will be contrasted with beliefs that receive negative information. Similar to evaluations and beliefs, several intentions towards actions are expected to change in a negative direction. To determine which scores have to be reversed, the categories of expected direction of evaluation change were used. This creates a problem for those actions that are influenced in two opposing directions. For example for actions with positive outcomes (attitudes and subjective norm are expected to become more positive) but low control (perceived control is expected to decrease) it is unclear whether intentions will become stronger or weaker. Since in principle all three variables are expected to influence intentions[28] these opposite changes might cancel each other out. Therefore I decided to use only those categories in which all information (related to outcomes, referents as well as control) points in the same direction. With regard to intentions, only those categories in which all evaluations are expected to change in the same direction were used in this analysis. So e.g. category 4, in which attitudes and norm are expected to become more negative but control is expected to become more positive, is not used. This leaves a maximum of 69 scores on intentions, of which 66 are expected to increase and 3 to decrease.

### 5.5.2 Ajzen variables

For measurement of the variables in the Ajzen theory, existing scales are used as much as possible. However, since the time required of respondents has to be limited as far as possible, only a subset of the items of the original scales are used. In addition, since this study includes different cases and participant backgrounds, different attitude targets will need to be measured. In order to ensure comparable measurement, the phrasing of items will have to diverge as little as possible between targets. For this reason, the format of questions on evaluations, beliefs and intentions is similar for all respondents but each question refers to specific behaviours. Behavioural options are either specified by the researcher or measured in a free format, i.e. participants are asked to define relevant options for themselves. An example of a behavioural option is *'recruiting more employees with an entrepreneurial orientation in our research department'* (case 3). In the subsequent sections of the pretest and posttest, the evaluation items do not include a full description of the behavioural option but refer to the previous description of the option. For instance participants are asked to indicate to which extent *option 1* (rather than 'recruiting more employees with an entrepreneurial orientation in our research department') is beneficial. All items are measured on a five-point scale from strongly agree to strongly disagree.

*Behavioural, normative and control beliefs*

Section 5.4.3 described how beliefs were measured using two scales: evaluation of the attribute (from 1: very unimportant, to 5: very important) and belief strength (or the relation between behaviour and attribute, from –5: strong negative effect, to 5: strong positive effect). Please recall that attributes are the outcomes, referents and threats or opportunities related to a behavioural option. Ajzen (1991: 192) raises the issue of the scaling of belief strength and evaluation. The theory does not include any propositions on whether scales should be measured in a unipolar (for instance from 1 to 7) or bipolar (for instance from –3 to +3) fashion. Ajzen proposes to use a linear transformation of both scales to increase the correlation between belief-based measurements and semantic differential measurements. He concludes that for modal

[28] Although section 7.4.2 shows that control has only a small influence on intentions.

salient beliefs, a bipolar score of both strength and evaluation measurements ensures optimal correlations. Modal salient beliefs are not necessarily salient for each respondent, and a bipolar scoring enables respondents to express the falsity of a belief. According to Eagly and Chaiken (1993: 234), bipolar scoring of evaluation corresponds to the general assumption that evaluations can range from negative to positive. However, there is some discussion on the bipolar scoring of strength of beliefs. For strength of self-generated beliefs, Ajzen and Fishbein (1980: 71) recommend unipolar scoring. Eagly and Chaiken (1993: 234) recommend unipolar scoring for both self-generated and modal salient beliefs, as this in their view best represents the subjective probability of beliefs. In this study I will follow Eagly and Chaiken's approach and score both sets of beliefs (model salient beliefs specified by the researcher and self-generated beliefs) in a similar fashion, using a bipolar score for evaluation and a unipolar score for strength. This means that both the score for belief strength will be recoded (1 to 11 instead of –5 to +5) as well as the score for evaluations (-2 to +2 instead of 1 to 5)[29]. The product of belief strength and evaluation, summed over all beliefs will be used as a belief-based measure of evaluations. Since each belief reflects a separate aspect of cognitions on behaviour, the scale of belief-based measures is not expected to refer to a single concept and will therefore not be tested for reliability.

With regard to normative beliefs, two additional questions are posed. In the posttest a question on important referents is included (cf. Felling, 1974). In the interviews respondents are asked whether all stakeholders and areas of expertise were represented in the modelling sessions.

*Attitude, subjective norm and perceived behavioural control*

Attitude towards behaviour is generally measured using a semantic differential of several items (Ajzen and Fishbein, 1980: 55; Madden et al., 1992: 6). In order to limit the size of the questionnaire as much as possible, in this study attitude is measured with two items. The items are anchored by very beneficial – very harmful and very good – very bad. The alpha reliability coefficient (or correlation between both items) for the pretest is .78 (n=76), for the posttest .93 (n=76), which is satisfactory.

Subjective norm was measured by asking subjects to respond to a single item, suggested by Ajzen and Fishbein (1980: 57): '*Most people who are important to me, think that I should implement option 1 in* [time period of concern]'. This item could be scored from strongly agree to strongly disagree.

For perceived behavioural control, two items of Madden et al. (1992: 6) scale of four items were used: '*Implementing option 1 in* [time period of concern] *is* very easy – very

[29] Appendix D, section 3 reports on differences between self-generated beliefs and beliefs generated by the researcher.

difficult' and '*The number of events that could keep me from implementing option 1 in* [time period of concern] *is* very large – very small'. The alpha reliability coefficient for the pretest is .20 (n=86), for the posttest .60 (n=80). It is difficult to find an explanation for the low reliability in the pretest. The fact that the first item is phrased in a negative sense might lead some respondents to choose an answer opposite from their intended choice. However, this does not explain the increase in reliability from pretest to posttest. Although the coefficient in the pretest is low, scales will be used unchanged.

*Intentions and behaviour*

Madden et al. (1992: 6) measure behavioural intentions with three items. Again, in order to limit the size of the questionnaire as much as possible, in this study two of their items were employed: '*I intend to implement option 1 in* [time period of concern] and '*I will make an effort to implement option 1 in* [time period of concern]'. These items could again be answered on a scale from strongly agree to strongly disagree. The alpha reliability coefficient for the pretest is .94 (n=70), for the posttest .93 (n=67), which is satisfactory.

As described in section 5.4.3, behavioural options are either identified by the respondent or the researcher. The interviews provide an additional check on the interpretation of options mentioned in the questionnaire and in addition are assessed in a free format, i.e. participants are asked if any changes in working behaviour occurred. These changes are compared to changes observed by the project gatekeeper and analysis of documents.

### 5.5.3 Process quality and intervention elements

In this section three topics are addressed: the main mechanism element, ability to process, the subjective comparison to a control group and the separate components of group model building.

*Ability to process information*

Ability to process information is measured with a scale consisting of eight Likert-type items. Each item could be answered on a five point scale ranging from strongly agree to strongly disagree. An example is: 'The sessions were characterised by open communication.' The following items are included in the scale:

1. open communication
2. clear and understandable communication
3. equal participation
4. ample opportunity to raise issues about which opinions were divided
5. pragmatic and clear focus
6. attention to ideas and opinions

7. absence of dominance of discussion by participants
8. absence of time pressure

The eight items are assumed to refer to the same concept. The data from the study by Rouwette et al. (1997) will be used to see if this is correct. The subjects in this study are 49 participants in the Marco Polis management game. There are several reasons to use data from this study to analyse the process quality scale. First, the intervention is similar in that it uses simulation and facilitation in discussion of a real world problem. The gaming simulation differs from group model building in that it does not employ a system dynamics model. However, I assume that the similarity in intervention approach outweighs the differences introduced by the specific modelling approach. Second, the data from the present study on group model building potentially confound differences between cases with differences between process elements. If for instance the group of participants is different between two cases, this is likely to introduce a difference in the score on equal participation. In order to assess the dimensions of process quality, it seems better to use data on a homogeneous group of subjects. Since the study by Rouwette et al. (1997) employs subjects from a single organisation participating in a single intervention, there is a smaller chance that contextual variables introduce differences in process scores.

Since four persons did not complete all questions on process quality, 45 subjects will be used in the analysis of data. Factor analysis with extraction of factors with an eigenvalue exceeding 1.0 leads to the extraction of three factors.

| *Factor* | *Eigenvalue* | *% variance explained* |
|---|---|---|
| 1 | 3.11 | 38.9 |
| 2 | 1.42 | 17.7 |
| 3 | 1.02 | 12.7 |

*Table 5.3 Eigenvalues and percentage of variance explained for ability to process (before rotation)*

Two reasons make a three factor model for these data likely: a. the drop in eigenvalue after the third factor. This is called the Scree-test (Kim and Mueller, 1983: 44), and b. the low eigenvalues of subsequent factors. However, inspection of the item loadings shows that item seven and eight are the only ones to load negatively on the first factor. Item-total correlations for these two items are below .1. After removal of these two items the percentage of explained variance using one factor is 39.3% which is satisfactory. The following table shows item-total correlations for a scale including all items, and for item one to six.

| *Item* | *All items included* | *Without items seven and eight* |
|---|---|---|
| 1 | .59 | .68 |
| 2 | .32 | .53 |
| 3 | .43 | .55 |
| 4 | .25 | .44 |
| 5 | .31 | .50 |
| 6 | .17 | .51 |
| 7 | .09 | |
| 8 | -.14 | |

*Table 5.4 Item-total correlations for 'ability to process' scale, using all items and items one to six*

For all items the alpha reliability coefficient is .44 while for the scale consisting of item one to six the alpha reliability coefficient is .78. A second (unpublished) application of the Marco Polis management game provided additional data for analysis of this scale. An analysis on the 62 subjects in both cases showed a pattern similar to the one above. I will therefore proceed with a scale for process quality consisting of six items.

In addition, subjects were asked to which extent they feel group model building was efficient and successful. These Likert-type items could also be answered on a five point scale ranging from strongly agree to strongly disagree. The items on efficiency and success will be considered separately in the analysis of results.

*Evaluation in comparison to a control group*

The second part of the hypothesis on process quality concerns the subjective comparison to a control group. For this comparison a scale developed by Vennix et al. (1993) was used. This scale consists of seven Likert type items. An example of an item is 'If you compare these meetings, using various techniques such as causal loop diagrams, with *normal meetings or conferences* in which you discuss *similar problem*s, would you say these meetings give *more* insight compared with normal meetings?' Each item could be answered on a five point scale ranging from strongly agree to strongly disagree. Vennix and Rouwette (2000) employ this scale in five group model building cases. They report data on a total of 40 subjects who answered all questions in the scale. Factor analysis with extraction of factors with an eigenvalue exceeding 1.0 leads to the extraction of the following factors.

| Factor | Eigenvalue | % variance explained |
|---|---|---|
| 1 | 3.61 | 51.6 |
| 2 | 1.16 | 16.5 |

*Table 5.5 Eigenvalues and percentage of variance explained for comparison to normal meetings*

I will again use the Scree-test and drop in eigenvalues to determine the number of factors. The Scree-test shows a drop in eigenvalue after the first factor. In addition, subsequent factors have low eigenvalues, which again suggests a one factor model. Analysis of item-total correlations indicate a satisfactory correlation of items to the scale. Item-total correlations range from .42 to .76, which is well above the lower limit of .20 suggested by Van den Brink and Mellenbergh (1998: 350). The alpha reliability coefficient is .83 which suggests that the scale can be used without changes.
Intervention elements
Lastly, the intervention elements need to be considered. Intervention elements are evaluated with one item each, for instance 'To which extent did you feel that the facilitator contributed to the overall effect of the sessions?' The following eight items are included in the scale:

1. projection of diagrams
2. facilitator
3. opportunity for open discussion
4. causal loop diagrams
5. parameter estimation
6. model analysis
7. data analysis
8. analysis of model output

The scores on these questions ranged from –5 (obstructed the sessions very much) to +5 (contributed very much to the sessions). In section 2.5 the relation between group model building elements and goals was discussed, and two main elements were identified: modelling and facilitation. The questionnaire addresses these higher level elements in more detailed terms; the first three items for instance separate facilitation into the contribution to the overall effect of the group memory (projection of diagrams), the facilitator and the opportunity for discussion. It is useful to assess to which extent the data on the separate items reflect the two higher level elements.

In determining the underlying components of intervention elements, the last three items will not be considered. Since these items concern quantitative models, they were only used in a few cases. For model analysis, only five measurements are included, for data analysis nine and for analysis of model output eight. Analysis of the first five items shows that only one factor can be found in the data: the first factor has an eigenvalue of 3.634 which drops to .836 for the second factor. Item-total correlations are between .59 and .84, while the alpha reliability coefficient of the scale consisting of five items is .88. It seems therefore that the two higher level elements, modelling and facilitation, cannot be found in the data. In the following, intervention elements will be considered in isolation as I am interested in assessing the relative contribution of separate elements to the overall effect of group model building.

### 5.5.4 Argument quality

Argument quality is measured using ten Likert-type questions in the posttest questionnaire. Items are based on the decision elements considered by Janis and Mann (1977). An example of an item is 'In the meeting all relevant options were considered'. Items could be answered on a five point scale ranging from strongly agree to strongly disagree. The expectation is that all elements refer to a single concept and correlations between items will therefore be described. In considering these correlations we need to keep in mind that data are aggregated over different problems and participant backgrounds. It is conceivable that in a specific application of group model building, all options relevant to one particular participant were taken into account, while another participant feels not all options for her of her organisational unit have been considered. Although the interpretability of the aggregate data is hindered by these factors, correlations between decision quality items are presented in the following.

The data on the five cases (n=26) show high item-total correlations with the exception of item 4 on the costs of decision options. Item-total correlations for the other nine items are above .33. The alpha reliability coefficient for ten items is .79. After removal of item 4 the alpha reliability coefficient shows a small increase to .81. The result of the factor analysis for nine items again shows a drop in eigenvalues after the first factor (the eigenvalue of the first factor is 3.652, of the second factor 1.661). In conclusion, the items on decision quality correlate highly with the exception of cost of decision options. The costs of decision options are considered separately in chapter seven on results.

### 5.5.5 Client and problem variables

Two contextual elements were considered important for this study: individual characteristics and problem characteristics, i.e. complexity. The latter will be measured qualitatively for each case. The score of each case on indicators for problem complexity is included in the case descriptions in the following chapter.

The main variable on the individual level is motivation to process. This was measured with two questions: 'How important is this problem to your organisation?' and 'How important is this problem to you personally?' In cases 1 to 3 both are measured with five point Likert items with answers ranging from very important to very unimportant. In case 4 and 5, organisational importance was assessed for each of the three options separately, e.g. 'Please indicate how important maintenance and renovation is to you organisation'. These questions were again formulated as five point Likert items with answers ranging from very important to very unimportant. Individual and organisational importance are measured in the pretest as well as in the posttest, since I expected the problem structuration in the intervention to result in a different perception of problem importance. There are only 15 complete sets of answers for the four items, which makes it difficult to analyse the dimensions of motivation to process. Pretest measurements show a low item-total correlation of .32 each. For posttest organisational importance the item-total correlation is .09, while posttest individual importance has a correlation of .00 to the scale. One reason for the low correlations are the changes in scores from pretest to posttest, which are discussed further in appendix D. The alpha reliability of the scale of both individual importance items is .49 (n=15); for the scale of the two organisational importance items alpha reliability is .72 (n=17). Since reliability of the first scale is low, the scale consisting of pretest and posttest organisational importance will be used as an indicator of motivation to process information.

As described in section 5.4.6, three other client characteristics were included in the analysis: the extent to which participants can implement conclusions, their age and years working with the organisation. The first characteristic, control over implementation, was assessed in the interviews and by document analysis. In the interviews respondents were asked to which extent they could set priorities in the problem addressed in the modelling sessions. This question addresses control generalised over all actions in the problem.

In the document analysis control was determined for each specific action, by determining whether the respondent's function allowed for direct control over the action. For example the action 'setting up a joint task force with other stakeholders in the problem' was judged to be only under indirect control since, although the respondent has some control over the action, other stakeholders are able to prevent implementation.

Age and years working with the organisation are assessed in the posttest questionnaire by a single item each.

## 5.6 Summary

In this chapter the hypotheses, design and operationalisation were described. Hypotheses are based on social psychological theories: the theory of planned behaviour (Ajzen, 1991) and two persuasion theories (Chaiken et al., 1989; Petty and Cacioppo, 1986). The following table depicts the variables considered in this study, data gathering methods and the process followed for variable construction.

| *Variable* | *Data gathering method* | *Variable construction* |
|---|---|---|
| **Context** | | |
| Client organisation* | Interview gatekeeper | Organisation sort, sector and size |
| Problem complexity* | Content analysis | Qualitative: analytical and social complexity<br>(cf. Hickson et al., 1986) |
| Motivation to process information | Questionnaire | Scale of two items on importance to organisation<br>Two separate items on importance to individual |
| Ability to implement conclusions | Interview participant<br>Content analysis | Qualitative<br>Qualitative |
| Age | Questionnaire | One item |
| Years working with organisation | Questionnaire | One item |
| **Mechanism** | | |
| Participant characteristics* | Interview gatekeeper | Number and function |
| Consultant* | Observation | Name consultant organisation |
| Duration* | Content analysis | Time involvement of participants and project duration |
| Techniques employed in the intervention* | Observation | Qualitative |
| Persuasive content | Content analysis<br>Interview participant | Coding procedure<br>Qualitative check by participants |
| Model characteristics* | Observation | Model size, qualitative or quantitative model, use of a preliminary model |
| Ability to process information | Questionnaire | Scale of six items (cf. Rouwette et al. 1997)<br>Two separate items on dominance and time pressure<br>Two items on overall success and efficiency |

| | | |
|---|---|---|
| Evaluation in comparison to control group | Questionnaire | Scale of seven items (cf. Vennix et al., 1993) |
| Intervention elements | Questionnaire | Eight items (cf. McCartt and Rohrbaugh, 1989; Vennix et al., 1993) |
| Argument quality | Questionnaire<br><br>Interview participant | Scale of nine items (cf. Janis and Mann, 1977)<br>One separate item on costs<br>Qualitative |
| **Outcome** | | |
| Conclusions/ dissemination* | Interview gatekeeper | Qualitative |
| System changes* | Interview gatekeeper | Qualitative |
| Options* | By researcher/<br>Questionnaire | Two to four items identified by problem analysis/<br>Two to four items in open question pretest |
| Attitude towards behaviour | Questionnaire | Scale of two items (cf. Madden et al., 1992) |
| Subjective norm | Questionnaire | One item (cf. Ajzen and Fishbein, 1980) |
| Perceived behavioural control | Questionnaire | Scale of two items (cf. Madden et al., 1992) |
| Beliefs | Questionnaire<br>Interview participant | Scale of three to seven items<br>Self-generated/ researcher<br>Normative belief: open question |
| Intention | Questionnaire | Scale of two items (cf. Madden et al., 1992) |
| Behaviour* | Interview gatekeeper | Qualitative |

*Table 5.6 Data sources and construction of variables ("/" indicates alternative options with regard to data sources or variable construction; scales refer to final scales; variables marked with * are measured qualitatively and, with the exception of options and behaviour, reported in the case descriptions in chapter six)*

# Chapter 6 Case descriptions

## 6.1 Introduction

In the previous chapters I have described group decision support systems and their expected impacts on decision making groups. In the second chapter one of these approaches, group model building, was chosen for this study. Group model building combines system dynamics and facilitation, and aims to help managers in working on complex problems. Ultimately, group model building was expected to bring about implementation of conclusions, leading to system improvement. Implementation in turn was seen as a result of other expected benefits of modelling, i.e. an increase in the quality of communication between managers, refinement of mental models and creation of a consensus view. The third chapter surveyed the empirical literature on group model building, to see which outcomes were reported consistently across different applications. An important distinction was made between context (the client and problem for which modelling is used), mechanism (how modelling changes the client or problem) and outcome, e.g. refinement of mental models or implementation. Chapter four described a preliminary conceptual framework on the mechanism through which group model building brings about these goals. This framework was used in the previous chapter to formulate research hypotheses. Hypotheses were formulated on the modelling process, changes in participants' cognitions and evaluations, and quality of the resulting decisions. It was argued that in order to test the expected effect on evaluations and cognitions, the respondent group needed to consist of participants involved in a real world problem. In this chapter, five modelling projects are described which will be used to test the hypotheses specified in the previous chapter.

Two considerations led to the assessment of effectiveness in a series of projects. First, the number of participants involved in a single group model building intervention is typically rather small. In order to obtain satisfactory statistical power, a series of interventions will need to be assessed. Second, evaluating more than one intervention makes it easier to go beyond the particulars of a specific case and increases the confidence in generalising results to the larger population of interventions. The purpose of this chapter is to sketch the general characteristics of each of these cases. The focus of the description of these five cases is on objective variables in the context, the intervention and the outcome. Pawson and Tilley (1997) make a clear distinction between objective variables and the interpretation of these by persons involved in the situation. They argue that the researcher's contribution to the evaluation of an intervention is to specify a possible mechanism, while stakeholders are in the position to say whether or not the mechanism applies to them (Pawson and Tilley, 1997: 164):

> *'The ultimate validity question, however, is not whether a ticked box is a pure representation of a subject's attitudes, or whether some extended quotation of their words is faithful to their beliefs. The true test is whether they capture correctly those aspects of the subject's understanding which are relevant to the researcher's theory. … [Subjects] will know better than anyone in what ways and to what extent their reasoning and choices have been changed during the initiative. To this extent they are 'mechanism experts'. The research question tested through them, however, will be about 'mechanism salience'.'*

It seems useful therefore to separate the description of objective case characteristics from their interpretation by subjects. Subjective variables are the topic of the next chapter.

The separation of objective and subjective characteristics enables us to test the assumption that in all cases participants are influenced in a similar way. The proposed mechanism is that in each case modelling helps in eliciting and structuring arguments for evaluation change, which eventually will lead to changes in behaviour. In chapter two the differential impact of particular model formats (qualitative, small quantitative and large quantitative models) was described. Section 3.6.4 pointed out that qualitative models are less likely than quantitative models to lead to commitment, consensus and system changes. They are equally likely to foster communication quality, insight and behavioural change. Qualitative models were also more likely than quantitative models to be used in messy problems. In other words, different outcomes can be explained by differences in context, mechanism, or both. In anticipation of the full discussion in chapter seven, I will only formulate the assumption here that these differences do not reflect qualitatively different mechanisms but merely differences in the extent to which the mechanism is effective. The longer time investment and more structured problem situation make it more likely that in quantitative modelling projects persuasive arguments are elicited, which are in turn more likely to lead to consensus and implementation in the form of system changes. I expect that in comparison to projects addressing very complex issues, these projects devote less time to discussion of differences in terminology between participants, divergent goals and uncovering relevant information. It is relatively easier to identify relevant information on the basis of which arguments are generated. The differences found between types of models are thus explained by the same mechanism. However, many more differences between cases can be found and are considered relevant to a project's outcomes, e.g. the level of conflict between participants (Vennix, 1996: 174). By first describing objective case characteristics, differences between cases are clarified and the description of subjective variables of the following chapter is put into perspective.

In this chapter the five group model building projects are described with regard to objective context, mechanism and outcome elements. Objective context elements are characteristics of the client organisation (type, sector and size) and problem (analytical and social complexity). In assessing social complexity it is useful to note that this concerns stakeholders in the problem, which are not necessarily present as participants in the sessions. The model for the Ministry of Transport e.g. includes decisions by network providers, which are not represented in the sessions. However, the objectives and influence of network providers add to the complexity of the problem that is modelled in the sessions. Therefore the interests in the problem, not those present in the sessions, are used to estimate social problem complexity.
Objective mechanism elements include the number of consultants and participants, participants' function, duration of the intervention, and techniques used. The perception of context and mechanism (problem importance, perceived ability to process information, evaluation of intervention elements, perception of argument quality) is addressed in chapter seven.
Likewise, this chapter describes objective characteristics of outcome, e.g. how project conclusions were reported and disseminated to other parts of the organisation(s) involved, and whether conclusions were (already) taken up. Subjective outcomes, i.e. changes in cognitions, evaluations and behaviour, are discussed in the following chapter. In summary, for each case the following is described:

- project background: background of the client and motive for starting the project;
- context: client organisation and problem characteristics;
- mechanism: objective intervention characteristics, i.e. participants and facilitators, project duration, techniques used, model characteristics;
- outcome: project report and conclusions, dissemination of conclusions and implementation.

The elements in each of these categories are gathered from the meta assessment of group modelling projects described in chapter two. The mechanism elements closely resemble those mentioned by Vennix (1996 : 174): number of participants, facilitators, techniques employed (quantification, preliminary model, workbooks, group process technique) and project time[30]. The last section of this chapter provides a summary on important indicators for each of the cases.

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[30] Vennix (1996: 174) also includes 'level of cognitive conflict' as one of the main differences between modelling projects. This is subsumed here under problem characteristics as 'analytical complexity'.

In the following I will use the term 'clients' to refer to the initiators of the project working with the client organisation. In the terminology of Richardson et al. (1992) this would refer to the gatekeeper. The modelling team refers to the facilitators, i.e. the modeller, process and content coach and the observer. Facilitators and clients make up the project team.

## 6.2 Safety in a city district

*Project background*

The clients in this case are the manager Integral Safety and one of the City District managers in a medium-sized city in the Netherlands. The direct reason for the project were the disturbances of the public order in a specific city district on new year's eve of 1998. These disturbances and the increasing perception of inhabitants that the neighbourhood was unsafe were judged unacceptable by various parties involved. The neighbourhood was characterised by a higher than average level of criminal activities, illegal use of houses, trespassing and harassment by youths, intimidation and violence against inhabitants. The actors involved have developed and implemented several plans to change the situation but to the present this was to no avail. It was believed that previous plans failed to take impact because they lacked an integral perspective on the problem.

*Context*

A diverse group of parties was responsible for aspects of the problem. Inhabitants were organised in an association. Violations of the law were the responsibility of the police, which also included so-called networkers who operated specifically in this district. Several departments of the city administration were involved in such aspects as the social department, tax, inspection of buildings and public space, and coordination of sports activities. Several social workers operated in the district. The local primary school played an important role for young children and their parents. The majority of apartments and houses were rented from one of the three housing associations operating in the district. Most stakeholders had been involved in the problem for a long time. They worked together with the other groups and frequently had developed an acquaintance with individual representatives of those groups.

On more than one occasion, the clients and participants in the modelling workshops expressed their concern over the developments in the city district. It was felt that the district developed into a 'no go area' and the situation was ready to 'explode'. The situation had resisted attempts at change for more than ten years. The modelling intervention was a new way of handling the problem, and because of the direct involvement of stakeholders highly visible. Participants expected the city administration to take action. From the start of the project it was made clear that the resulting report would be presented to the mayor and city council. The clients expressed that by initiating this project they committed themselves to taking due notice of the conclusions, and taking them one step further in working out an action plan for the district.

In sum, the elements of social and analytical complexity described by Hickson et al. (1986) can all be found here. Examples are the seriousness and endurance of the problem's consequences, the involvement of a variety of interests who exert different levels of pressure, and the dissimilar objectives of various interest groups (e.g. inhabitants versus police).

*Mechanism*

The aim of the intervention was formulated as drawing a map of the situation. It was expected that a consensus view would be created on the problem and broad strategies for alleviating the problem. Because of the complexity of the problem, detailed actions and an implementation plan were explicitly not included among the project expectations. Three facilitators from Nijmegen University were involved. The facilitators and clients met five times before the first session. The choice of participants was largely the responsibility of the clients, and participants were invited to contribute on a personal basis, i.e. not as representatives of their respective stakeholder groups. The first modelling session lasted half a day and started with an informal meeting and lunch. A total of 17 participants were invited, of which 16 were present including one person replacing a colleague. After introductions and lunch, participants gathered in a group decision room. After an explanation of the purpose of the meeting and the agenda, a short explanation on qualitative modelling was given. The group took part in a Nominal Group Technique on problem elements, using GroupSystems. After the facilitator and the group had walked through the list of elements, these were used to build a causal loop diagram. This resulted in a small diagram of 17 variables by the end of the first session. In between the first and the second session, workbooks were used to report back conclusions and to ask for clarification on several elements of the model. Participants were asked to send in their answers.

Approximately one month after the first session participants met for the second time, again for about four hours. The facilitators had categorised problem elements, and participants started the second session by indicating which elements in each category were the most important to include in the diagram. After refining the model, the group split up into subgroups and discussed interventions in the problem based on the model's structure. The session ended with a short presentation of each subgroup, and a final causal loop diagram of 38 variables and ten major feedback loops. Results

were gathered in a concept report, which was discussed by the clients and facilitators in a meeting. Although initially only two sessions were planned, it was decided to convene the participants for a third session to discuss the concept report. The concept report explained the final model by going through its submodels one by one.
One month after the second session, the last session took place. In this two-hour meeting submodels were presented and discussed separately. The group suggested only minor changes in the wording of the report and model variables. Changes were incorporated in the report, which was handed over to the clients.

*Outcome*
Several meetings between the two clients and the facilitators were held to discuss concept versions of the report. The final version was presented two months after the last session. The document included a description of the model and a discussion of nine areas for possible improvements. These areas followed from an analysis of feedbackloops and variables under control of one of the stakeholders present in the sessions. The report's recommendations for interventions in the problem were very similar to the outcomes of the subgroup discussions in the second session. Typically, they were formulated at a high level of abstraction, describing the preferred direction of change of the steering variable and expected effects. An example is the following: 'Promote education and limit the number of drop-outs. This will enable more inhabitants to set up a business, since many opportunities in this field require a diploma.' This is followed by more specific notions on how to promote education and long-term effects of this intervention. Although specifics of how to foster education go beyond the variables included in the model, long-term effects are deduced on the basis of the feedbackloops included in the model.
The report was presented to the mayor, who approved it for presentation to the city council. However, the mayor also decided that the project report should be accompanied by a detailed action plan including costs and a time frame, before the council could read it and decide on further actions. At present, the action plan is being developed and the report has no official status yet. In the interviews after the intervention, several participants described how they already implemented a number of conclusions in the plan, in particular conclusions that elaborated on already started initiatives. So even while a definite action plan was not yet drawn up, implementation of conclusions started on a small scale.

## 6.3 Ministry of transport

*Project background*

The client in this case is the Directorate General of Telecommunications and Post (DGTP), a department of the Ministry of Transport, Public Works and Water Management. DGTP is responsible for a significant part of the Dutch government's policy with regard to information and communication technology (ICT). DGTP's focus is on ICT infrastructure, while other departments are responsible for 'content areas' such as education, public health or legislation. In the last decade, the department has separated itself from the Dutch telecommunications company PTT, now KPN. The responsibility for supervision of competition between telecommunications providers was delegated to a separate organisation, OPTA. At present the Dutch laws on ICT are to a great extent formed by the European Union, DGTP's task being to translate these into Dutch legislation. After the separation of KPN and OPTA, the need has developed to create a vision for the Dutch ICT policy. This vision would provide a sense of direction for both DGTP and other parties affected by its policies. These partners include telecommunications providers such as KPN, who have to make large investments in infrastructure and need clarity on e.g. public health regulations. Other important partners are the ministries responsible for content areas. The vision for DGTP is at present discussed in very general terms. The main elements are creating a favourable climate for telecommunication providers while guaranteeing access to services for every Dutch citizen. In addition to an abstract vision, there is a lack of information on the impact of DGTP policies. Due to the rapid and unpredictable developments in telecommunication technologies, estimation of long term developments is difficult. Both of these needs urged the Strategy section to start a project in which members of different DGTP sections would try to formulate a vision on ICT developments.

*Context*

Above the parties in telecommunications in the Netherlands were outlined briefly: the European Union and various ministries who jointly develop legislation in this field, telecommunications providers and the Dutch population as the customers for ICT services and target group for governmental policies. DGTP consists of five sections: Infrastructure, Safety, Market Functioning, Information Society and Telecommunication. In addition there is an Agency representing the Radio communication Services. The sections are supported by three staff services: Strategy, Legal Affairs and International Affairs. The modelling sessions were attended by one representative of each of these groups, with the exception of Strategy which was represented by both initiators of the project.

The need for a coherent vision on the desired situation of DGTP and for instruments to create such a vision, was increased by the expected introduction of three new services on the Dutch communication market: a new standard for mobile telephony (UMTS), wireless data connection (WLL) and digital TV (DVB-T). It was felt that more clarity on the DGTP strategy would greatly help in facilitating the introduction of these services. In order to develop regulations for each of these services, DGTP would need to carefully balance demands of providers and societal consequences, e.g. equal access to services.

In sum, the elements of analytical complexity described by Hickson et al. (1986) can also be found in this case, e.g. seriousness and endurance of consequences. Social complexity is high is well, which can be concluded from the divergence of interests of the national regulator versus market parties, and the opposing interests of competitors on the telecommunication market. Please note that although market parties were not present in the sessions, they exert influence in the problem and therefore contribute to its social complexity (see section 6.1).

*Mechanism*

Four general aims were formulated for the modelling project: providing more clarity on the structure of the telecommunications field including the three new services, increasing experience with the system dynamics methodology, increasing communication between sections within DGTP and identification of possible knowledge gaps. Three facilitators from Nijmegen University were involved. The facilitators and clients met once before the first session. Again the clients were largely responsible for selection of participants. The two clients met twice with a group of participants to decide on the focus of the sessions. They decided to formulate the problem to be addressed as follows: 'Which factors play a role in the number of ways a consumer can gain access to communication services?' In the first session six participants were present. The session started with a short presentation on the purpose of the meeting and the agenda and an introduction of qualitative modelling. Participants were then asked to contribute problem elements, using Nominal Group Technique. In the remainder of the three-hour meeting a preliminary causal loop diagram was formulated. The model described processes surrounding the introduction and diffusion of a communication service at a general level, including elements such as number of providers, infrastructure in use, and customer value, without specifying details of a particular service. The main points of the discussion were reported back in a workbook, using the causal loop diagram to explain and relate arguments. Participants were asked to check if the model accurately described the expected diffusion of the three new services (UMTS, WLL and DVB-T).

In the second session the initial model was developed further, resulting in an enlarged model including two positive loops and one negative loop. Participants felt these loops explained observed behaviour in the field of communication services in the past years: after introduction of a new service there is a huge growth in the number of providers, followed by a decline as some of them are not able to make a profit. The session concluded with a detailed check of the model against the expected diffusion of DVB-T. The variables in the model turned out to be sufficient to describe the introduction of this service. Taking a concrete example for checking the model highlighted the influence of governmental regulations. The initial number of providers was for instance determined by the number of parties that were granted a license for a new frequency. Participants decided to focus on the role of government in the third session. The role of government could be clarified by identifying steering variables, goals or side effects of interventions. Guaranteeing a broad access to information services is one of the major goals of DGTP, but in order to include all responsibilities of the department (e.g. adequate reliability of communication infrastructure) a comprehensive scan of goals was felt to be necessary. The second workbook included the causal loop diagram and asked participants to identify goals for governmental communication policy.

The third session focused on identifying the three categories of variables important for policy making. In the discussion the following goals and policy levers were identified and added to the model:

| *Goal variables* | *Policy levers* |
|---|---|
| - customer value | - access capacity |
| - equality in access | - complexity for user |
| - competitive strength Netherlands | - coverage |
| - reliability | |

The session concluded with a discussion of the seven feedbackloops that were included in the new model. Although initially three sessions were planned, participants felt that an extra meeting could help in checking the model against expectations about the introduction of new services. In particular participants would like to see whether all relevant policy variables were included, to check whether feedbackloops might be able to generate observed behaviour and to identify major conclusions for policy development. The third workbook again captured the main points of the discussion.

Due to the holiday season, the last session took place two months after the third session. In the last meeting the introduction of GSM telephones was used as a reference mode of behaviour. Again the conclusion was that the model structure presented a possible explanation for observed behaviour. The major variables in the diffusion of GSM telephones were included and the feedbackloops offered possible explanations for historical behaviour patterns. Although the model was an adequate description of the general situation, participants concluded that for particular services additional variables needed to be added. This was expected to make the model too complex and therefore no changes were made in the model in this session. The meeting ended with a discussion of important areas in the model that needed to be elaborated. Three areas where DGTP lacked information were identified: relative expectancies of profit, customer value and number of service providers.

*Outcome*

After the last session, the clients convened a number of meetings with experts on particular services. The final report therefore was completed four months after the last session. The document described the model and the policy goals and steering variables for DGTP. An analysis of the seven feedbackloops in the model showed that goals were sometimes at odds with one another. E.g. strict regulations on reliability of communication infrastructure might increase costs for providers and thereby limit customer value. The report concluded with a brief description of the knowledge gaps mentioned above and areas for model refinement.

The model and report were discussed in further meetings with experts on particular services. In the evaluation interviews after the modelling sessions, participants indicated that the model also served as a reference when drafting policy notes.

## 6.4 Telecommunications provider[31]

*Project background*

The client in this case was the head of the human resource department of KPN Research. KPN is a Dutch company originating from PTT, the former government owned telecommunications provider. After the market for mobile telecommunication was opened up in 1995 and the market for land lines in 1997, competition on the Dutch telecommunication market has been increasing steadily. At the moment KPN is the largest Dutch telecommunications provider, concentrating its operations on the national and European market. An increasingly important element of this competition concerns adequate human resource management. KPN Research realised that human resource policies needed to be adapted in order to remain competitive. In addition, expected changes in organisation and management of KPN Research called for a different composition of human resources.

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[31] This project is described in a paper by Mooy et al. (2001).

*Context*
In order to bring about the desired changes in HRM policies, the HRM department planned to implement a new structure of personnel profiles. KPN Research's HRM department is primarily responsible for policies in this field, of which consequences extend to all 400 employees working within the research department. KPN Research operates as a network organisation, with employees in research positions reporting to their unit manager as well as to the managers of different accounts they are working on. Implementation of new HRM profiles would affect unit managers, account managers as well as researchers. For hiring new employees KPN Research largely draws on the pool of graduates of relevant (technical) universities in the Netherlands. In this they face competition of other providers and telecommunication research centres.

Although demand on the labour market had exceeded supply for some years already, KPN Research had not yet met with major problems in recruiting newcomers on the job market. KPN's position as the largest provider and reputation for innovation were thought to be largely responsible for this. However, in retaining researchers competition was increasingly felt. If researchers felt their development and learning did not proceed fast enough, other options were becoming available more and more. By using human resource instruments such as training, salary and changes in working conditions, KPN tried to retain the desired workforce. However, detailed understanding on the exact effect of instruments and how to employ their combination to the best benefit was lacking.
In sum, the elements of analytical complexity described by Hickson et al. (1986) can be found in this case as well. Since the problem largely concerns processes internal to KPN, there is no large divergence between goals of participants. Employees, managers and staff are expected to agree on higher level goals, e.g. profitability and continuous innovation. Social complexity is therefore estimated as 'medium' in this case.

*Mechanism*
The goal of the modelling project included both a methodological, evaluation and content aspect. KPN Research Business Modelling had experience in building system dynamics models for some years. In most of their projects the client demanded for content expertise as well, and model construction proceeded largely in an expert mode. The department wanted to increase its ability to use group model building. For this reason KPN modellers took part in a two days workshop on facilitation organised by Nijmegen University. In order to test the approach, it was decided to take on an internal project and have a facilitator of Nijmegen University present as a coach. A second expected benefit of this cooperation was the development of a

standard for evaluating the impact of this type of interventions. Apart from developing expertise in group model building, Business Modelling also wanted to be able to better measure the benefits of modelling so as to prove its value to clients. A suitable test bed for group model building was found in an important internal issue, the transition of KPN Research to new HRM profiles. KPN Research's HRM manager acted as the principal client in this project, while five members of Business Modelling were responsible for facilitation and model construction.
In a series of meetings with the client, the central problem was formulated as 'Which variables influence input, throughput and output of employees within each of the KPN Research HRM profiles?' The project team's aim was to develop a small quantified model. The time frame of interest was 2000 to 2005. Since data were largely limited to migration of the KPN Research population as a whole (not detailed for specific personnel categories), difficulties were expected in finding historical data. The fact that the large number of traditional competencies were not easily translated into the new profiles further complicated data finding. The participant group was expected to be the primary source of data, and the client and facilitators were both responsible for participant selection. The group consisted of 10 people, mostly HRM, unit and account managers working within KPN Research. One HRM manager from a department outside of Research was present as well. Before and over the course of the sessions, the group changed several times as participants were no longer able to spare time. Within Business Modelling, the project leader was promoted to another position after which the project group changed. In a series of meetings between the project team and a facilitator from Nijmegen University the schedule for the sessions was discussed. It was decided to use a preliminary stock and flows model as this was thought to visualise the migration between HRM profiles and provide a focus for the discussion.

The project started with individual interviews of all participants. The interviews served both to introduce the project and as a pretest of ideas and evaluations of the subject matter, to be used in the evaluation of the project. The outline of the project included a short preface of the methodology, introduction of the participant group, a time schedule for the sessions and expected contributions of participants. Since the HRM profiles were new to most participants, each interview devoted some time to their definition and relation to the current personnel categories. Seven profiles were identified as the major categories for the new HRM policy. Young academics would first flow into a starter profile. From there on three routes were possible: innovator, integrator and project leader. Each of the routes contained a junior and a senior profile.
The first meeting started with a round of introductions by the project team and each of the ten participants. The Business Modelling team included two modellers, a

facilitator and an observer. A preliminary model was presented and used to identify the relevant transitions in the HRM chain. This model consisted of a single stream of employees migrating through the innovator profiles: starter, junior innovator and senior innovator. Starters could promote to junior innovators, who in turn could proceed to the senior innovator profile. In addition, each profile had an input and output. The terminology was not expected to lead to problems, as the definition of each profile was addressed in the preliminary interviews. Participants were then asked to identify relevant variables connected to the various transitions using NGT. The focus in this session lay on the input of academics. A small model of 24 variables was developed that included three feedbackloops. All of the loops were positive and included the variable 'attractiveness of KPN Research as employer'. Results were reported back to participants in a workbook.

In the second session, one month after the first, the flow from junior to senior innovator was focussed on. The flow of junior to senior profiles was assumed to operate along similar lines for the other profiles. The session was attended by five participants, two modellers and one facilitator. Two observers, one person from Business Modelling and one from Nijmegen University, took notes during the meeting. After an introduction of new participants, the model constructed in the first session was explained. Participants were given a list of variables mentioned in the first session but not yet included in the model. The discussion on what influenced promotion from junior to senior innovator yielded a new model substructure, largely unconnected to the factors influencing recruitment. A total of five loops were identified. In contrast to the first session, two of these were balancing loops. Both involved the number of seniors limiting promotion opportunities, either because they limit the opportunities for juniors to participate in innovative projects or all available senior positions are occupied. A positive loop was created by effect of limiting undesired outflow on employee motivation. The two other reinforcing loops involved seniors. Firstly, senior coaching increases junior learning and thereby promotions to the senior profile. Secondly, seniors are needed in the acquisition process of innovative projects, which increase learning opportunities and thereby number of promotions. Results of the session were again reported back in a workbook.

In the three weeks to the third session, the model structure developed so far was translated into a quantitative model. A number of relations in the model turned out to be particularly difficult to define. As was expected beforehand, data on migration between HRM groups (traditional competencies as profiles were not yet implemented) were not abundant. Data that were identified included recruitments and job terminations for KPN Research as a whole. These data consisted of aggregate numbers and in some cases qualitative information included in e.g. application and exit interviews. The Business Modelling team was responsible for quantification, and the plan for the third session was discussed together with Nijmegen University facilitators. Various alternative agendas were discussed, including Warren's (2000) ideas on data gathering, various scripts described by Andersen and Richardson (1997) and Ford and Sterman's (1998) graph estimation procedure. Model development, data gathering and discussions on the session agenda proceeded more or less simultaneously. After much effort was put into equation formulation, debugging and behaviour validation, confidence in the model was judged adequate for presenting runs in the session. However, a number of equations involved rather intangible variables, resulting in very preliminary estimates of relations. It was decided to use model output to demonstrate the quantitative model to participants, but to devote the major part of the third session to the specification of relationships in the model. Seven participants were present in the last session and were facilitated by the same team as in session two. The meeting started off with an explanation of the assumptions behind the model developed so far, and the areas where further improvement was necessary, e.g. motivation of employees. The presentation of the first model runs met with approval of the participants, who prompted for testing out effects of parameter changes in the model. This was however planned as the last item on the agenda. After the presentation, participants worked on parameter estimation. The procedure described by Ford and Sterman (1998) was adapted slightly for this purpose. The facilitator asked the plenary group for an example of two variables, one having a non-linear effect on the other. Petrol prices and number of kilometres travelled were suggested. He then proceeded to draw the axis, measurement units and a number of data points. The participants were invited to think on whether there were any abrupt changes in the graph connecting the data points. How expensive should petrol be before a person limits his travel kilometres significantly? Participants entered into a lively discussion and seemed to pick up the procedure easily. One person asked which experiences the modelling team had with this method, and whether it was used more broadly. The facilitator and other participants responded that the extreme values were most interesting, while these would hardly ever be found in data sets. In addition, data would reflect the impact of other variables as well, making an effect difficult to interpret. Another plenary example focused on the effect of the proportion of junior to senior employees on the level of support for juniors. The estimation of this graph proceeded smoothly as well. After these two plenary exercises, the group was split up in two subgroups each modelling two non-linear relationships. The following relations were addressed:

- the effect of attractiveness of KPN Research as an employer on number of job applicants;
- the effect of percentage of hires on quality of input of employees;
- the effect of the proportion of junior to senior employees on growth opportunities for juniors;

- the combined effect of quality of juniors and proportion of junior to senior employees on migration of junior to senior.

The last effect prompted an interesting adaptation of Ford and Sterman's method. For estimating the combined effect of two independent variables, a matrix was handed out. Independent variables were plotted along the horizontal and vertical dimension, and their effect noted in each cell, as shown in the following figure.

| *Effect on the flow of juniors to seniors (F)* | | *Percentage of seniors (S)* | | | | |
|---|---|---|---|---|---|---|
| (as % of the number of juniors) | | 0 % | 25 % | 50 % | 75 % | 100 % |
| Quality juniors (Q) | very bad | | | | | |
| | poor | | | | | |
| | neutral | | | | | |
| | good | | | | | |
| | very good | | | | | |

*Table 6.1 Matrix to identify effects of two independent variables on one dependent variable (from Mooy et al. 2001)*

The changes suggested by participants were not immediately implemented in the model, and participants were cautioned to interpret results as very preliminary. In the last part of the session, they were asked to indicate expected results for changes in a steering variable. This part drew on Andersen and Richardson's (1997) and Richmond's (1997) suggestions for scenario runs. The percentage of applicants hired was selected for this purpose, and three values were tried out. Participants were asked to 'put a stake in the ground' by sketching graphs for average quality of KPN Research and migration of junior to senior levels. The outcomes turned out to differ from most participants' assumptions but were explainable from the model structure. The explanations seemed to be satisfactory to participants as no further model changes were proposed. The session was closed with a short evaluation of the project. Three participants, who had to leave the last session before the discussion on scenario runs, were later shown the runs in short individual sessions.

*Outcome*

The project's conclusions were not handed over in the form of a report. A short workbook of the last session was made and sent out to participants. The HRM managers that commissioned the project would be handed over the model and documentation in a familiarisation session. For participants the project ended with evaluation interviews.

## 6.5 Housing association east

*Project background*

The projects described in this and the following section are a direct consequence of the changes in Dutch housing policy in the 1990s. Traditionally, housing associations or corporations were responsible for renting houses to low income families in the Netherlands. A corporation might have an inventory of 1.000 up to 30.000 housing units. Until the end of the 1980s, financial continuity of housing associations was guaranteed by the Dutch government. In effect housing associations passed on requests for housing to a central administration, and were responsible for construction and maintenance of their housing inventory. Associations were not required to make strategic decisions, e.g. by anticipating on future demand for housing types. From 1988 on this situation changed, and associations were gradually made more independent from the Dutch government. Ultimately associations were expected to operate on a free market and take responsibility for balancing their revenues and expenditures. Gradually corporations gained more leeway in making investment decisions. An example of this is that from the mid 1990s on, more and more corporations constructed houses only to sell these to the private market, thereby gaining additional revenues. Additional innovations such as selling houses to tenants (so-called 'rent purchase') were introduced. The extent to which a particular association implemented these changes, depended to a great extent on its organisational form. Traditionally housing associations were organised as associations, where members (tenants) have a legal right to approve the annual account and budget. In addition the board of commissioners of an association has a legal right to advice the management on its policy. In order to increase its margin of influence, the management of many associations changed the organisational form to foundations. In a foundation members have no voting rights and the board has only a supervisory task. Another key actor in the environment of a housing association is the local council. The council is responsible for allotting the number of houses that can be newly constructed (the quota) to the public or private sector, i.e. property developers or private persons. The local council also determines the price per square meter for which land is sold.

In the transition to the new situation, corporations could appeal to their branch organisations for advice. One of the three branch organisations is the Dutch Christian Institute for Housing (DCIH). DCIH's consultancy department, Atrivé (formerly Marco Polis Advice), specialises in strategic consultancy, using a number of tools ranging from portfolio analysis to simulation gaming. Simulation gaming (for a description see Rouwette et al., 1998) proved successful in enabling members of housing associations to experiment with their new conditions. In order to extend the

use of simulation and gain a better understanding of the effect of different housing strategies, Atrivé commissioned the development of a generic model of housing associations (Vennix, 1996: 204). In 1994, construction of the model was started by a team of Atrivé representatives and system dynamicists from Nijmegen University. The model was developed in a series of sessions over a time span of about half a year. The final generic model includes a flow of housing construction, waiting lists, acquisition and use of land, rents, as well as a number of financial indicators (book values, reserves and current account). After development and subsequent testing of the model, Atrivé invited client organisations to engage in what they called strategic inventory management projects. These projects would rely heavily on the generic model which would be adapted to a corporation's specific circumstances.
Since then about a dozen housing associations engaged in this type of projects. Apart from configuring the model with the data of a specific corporation, several structural changes to the general model were made as well. A number of decisions that where included in feedback loops in the former model, were implemented 'by hand' in the new version. For example, while in the generic model houses had a life span of 50 years and were demolished afterwards, in the new model the number of houses scheduled for demolition could be specified per time period. Also further detail was added to the model, e.g. with regard to the type of houses. Where the original model included three categories of houses (low, middle and high class), more detailed models might include nine types of houses in nine different neighbourhoods, bringing the total to 81 different categories. Many other adaptations were made, with insights from one corporation informing decisions in subsequent projects and updates of earlier models.

In this and the following paragraph, the application of the generic model in two housing associations is described. In the remainder of this paragraph, a modelling project in housing association East is described. In order to ensure confidentiality, a fictional name is used. The client in this case is the director of a housing association in a small city in the Netherlands. The corporation is relatively small with an inventory of about 2,600 housing units and a management team of four persons. The corporation is organised as an association.

*Context*

The conversion to a free market left housing association East with relatively balanced revenues and expenditures. A temporary decrease in solvency was expected around 2010 due to an increase in loans, but the management was unsure about its size or significance. If unforeseen losses should occur, part of the housing inventory could be sold to their owners, generating additional revenues. The ultimate aim was to keep the number of housing units constant, which meant that selling or demolishing

houses had to be compensated by construction of houses elsewhere. The management's goal in this project was therefore not primarily financially oriented, but more directed toward assessing the effect of changes in their housing inventory. In addition the director thought the model a useful device to strengthen the strategic awareness of the management team.
After testing the model the managers expected to be able to configure data independently from the Atrivé consultant and use the model as a monitoring system. For this reason the final model was changed into a management flight simulator. In choosing and implementing policies, two other stakeholders needed to be considered: the board of directors and the city council. For making strategic changes, management needed the approval of the board of commissioners. In the acquisition of land, the city council is an important partner as it decides on the quota of houses for the public and private sector. The city council was therefore an important partner in negotiations on the price of land needed for new houses.
In sum, the elements of analytical complexity described by Hickson et al. (1986) can all be found here. Examples are the rarity of the problem (the recent privatisation presents the corporation with issues not encountered before), and the seriousness and endurance of the problem's consequences. Social complexity is high is well, which can be concluded from the divergence and imbalance of interests between tenants, the corporation and the city council.

*Mechanism*

After the project was launched in February 1999, the four managers of housing association East participated in modelling sessions on a weekly basis until April 1999. The maintenance and financial managers frequently met with the Atrivé consultant in individual sessions to discuss specifics of the model. In the process the model evolved to a quite detailed level. Comparisons of model runs and administrative data from the corporation led to changes in the model, but in several cases promoted changes in the bookkeeping system as well. In April 1999 model runs were presented to the board, although model testing was not fully completed. In the meeting with the board the assumptions behind the model were explained, a baserun presented and results of ten different scenario runs discussed. Each scenario combined different number of conversion of houses from one category to another, construction of new houses and sale of houses. Conversion of houses frequently boiled down to renovation and upgrading of housing units. Subsequently members of the board were invited to suggest scenario conditions of their own, including factors such as changes in interest, vacancy of houses, and unit selling prices. In general, members of the board were enthusiastic about the model and approved of its use to test policy options. In particular the interest on loans proved to have unexpected effects.

The model was developed further in weekly sessions until the end of June, while additional changes were made until March 2000. The final model included financial aspects, inventory management and demand for public housing.

In September 2000 negotiations with the city council started. In the negotiation the director of the corporation made frequent use of the scenario runs and additional model output. The main focus of the negotiations was the quota of houses to be allotted to corporation East. A total number of 300 houses could be allotted to either the corporation or the private sector. The city council's calculations showed a decrease in demand for public housing in the coming four years. The city councillor therefore was in favour of allotting a large part of the quota to the private sector. The system dynamics model was instrumental in showing that over a longer time period, demand for the public sector was stable. The model therefore contributed to the negotiations as a back up for the corporations' representatives, as it was able to calculate consequences of different propositions.

*Outcome*

The model resulted in a very detailed assessment of the consequences of proposed strategies. An important debate within the corporation was how to finance renovation and improvement of housing units. The management team was reluctant to increase loans as they were uncertain about future developments. Both the model and calculations on the basis of the existing bookkeeping system indicated the extent to which loans could be increased to finance renovation and improvement of housing units, without generating too much debts in the future. In the evaluation interviews, several managers remarked that the model provided a common point of departure in meetings. The model integrated diverse aspects of inventory management, finance and demand for houses, and was a useful addition to the traditional bookkeeping system: the system dynamics model was easier to configure with new data, provided a less detailed view and was able to show effects on a longer time horizon. The model was used for verifying the annual reports for 1999, 2000 and 2001. In addition several managers use the model regularly for making general estimates of policy outcomes. Evaluation interviews were held in March 2001, but updating and refinement of the model continued afterwards. While corporation East is considering changing from an association to a foundation, the model is expected to be helpful in presenting the consequences of this strategic change to the association members.

## 6.6 Housing association west

*Project background*

Similar to the project described in the last section, the project described here was a result of the changes for Dutch housing associations in the early 1990s. In the remainder of this paragraph, a modelling project in housing association West is described. In order to ensure confidentiality, again a fictional name is used. The client in this case is the director of a housing association in a small Dutch city. The corporation is relatively small with an inventory of about 2,200 housing units and a management team of six persons. Housing association West is organised as a foundation.

*Context*

Housing association West started on the free market with low financial reserves and high loans. An important aim of the modelling project was therefore to gain insight into maintenance and renovation costs. The corporation was planning major renovation and maintenance works, involving a large part of its housing inventory. Association West had no shortage of demand for its houses because of its location near Amsterdam. The construction of new houses was not an issue, since the city council did not issue quota for new building sites. The management team also expressed a desire to change from what they called an administrative organisation, to a demand-oriented organisation. This would involve setting up new services for tenants, e.g. rent purchase. The management team aimed to find a partner for a merger, by which the corporation would be able to access additional capital and capitalise on its demand pressure.

As in the previous case, the managers expected to be able to use the tested model independently from the Atrivé consultant, by configuring data and using the model as a monitoring system.

Similar to corporation East, corporation West is faced with an analytically complex problem (Hickson et al., 1986). The recent privatisation process presents the corporation with novel issues, in which decisions need to be made with wide ranging and enduring consequences. Social complexity is high as well, which can again be concluded from the divergence and imbalance of interests between tenants, the corporation and the city council.

*Mechanism*

In the modelling project in housing association West, three different phases can be distinguished. While the focus of the first phase was on a planned merger, attention in the second phase turned to a major restructuration of the housing inventory. In the last phase the model was used in developing a business plan. The first phase started in July 1998. At that time, the management team was preparing a merger with a regional housing association. Atrivé was asked to facilitate the merger process. Between January and June 1999, the board and management team of both corporations participated in six modelling sessions. In the sessions the generic quantitative model, described in the previous section, was used as a starting point. The 12 participants constructed causal loop diagrams around the factors that were included as exogenous variables in the generic model. Session results were reported back in workbooks. The aim of these qualitative modelling sessions was to develop a shared vision between both corporations. Due to the sessions, the management and board of both corporations appeared to have developed a consensus view on the aims of the new, merged, organisation. However, this consensus proved to be more apparent than real. In a later meeting led by the corporations' accountant, it became clear that housing association West favoured a much more innovative strategy than its intended fusion partner. Subsequently, the meetings between both parties were ended and the merger was called off.

Due to a change in management the focus of the modelling project shifted. The second phase started when in January 2000 the corporation's director resigned, and a member of the management team took over his position. The new management turned attention away from the planned merger to a planned upgrade of an apartment building. This upgrade involved demolition of 200 housing units and the construction of a dome in between apartment towers, for which a major investment was needed. Since corporation West was low on financial resources, financing this operation became the central focus of the modelling project. The generic quantitative model was adapted to the corporation's situation and further detailed with regard to housing inventory and financial aspects, in particular loans. Since demand was assumed unproblematic, this part of the model was not developed further. The development of the model mainly took place in the series of sessions of the consultant and individual financial or inventory managers. In configuring the model for the annual report of 1999, a difference in opinion developed between the Atrivé consultant and the corporation's financial manager. The financial manager estimated future maintenance costs at a lower level than the modeller did. The management team and the consultant discussed the issue in a series of meetings, during which the consultant was invited to change his assignment and become an internal consultant or interim manager. However, debate on the interpretation of the data continued and the use of the model as a long term planning aid was abandoned in the last months of 2000. From September 1999 on, the corporation's accounting system was based on a financial software package called Proficon. As Proficon covered loans and inventory management, it was used to answer many of the financial questions that were central in the system dynamics project.

The third phase of the modelling project took place in the first months of 2001. Around this time the national government strongly advocated corporations to develop a business plan along the guidelines of the balance scorecard and INK model (e.g. Maas, 2001). In addition, the corporation wanted to increase its insight into renovation and maintenance costs of its housing inventory. A member of the management team was asked to work out a business plan. In this phase the system dynamics model was used to provide the long term data needed for the business plan. The model was not adapted or configured with recent data. The Atrivé consultant and the manager responsible for the business plan jointly developed a plan in a series of meetings. The revised plan represents the strategic vision of the corporation, which prompted a number of changes in long term policies. In July 2001 the corporation merged with two smaller associations. The financial position improved due to selling of housing units and restructuring of loans. The management moved to a new head office and a separate back office was installed to improve service to tenants.

*Outcome*
In this case, the impact of the model is difficult to assess. The modelling project heightened the corporation's attention to client oriented service, particularly in the first phase. This preceded the national guidelines that were issued to this end. The increased attention to the customer, culminating in the installation of a front and back office, can therefore at least in part be attributed to the modelling intervention. In the second and third phase the model underlined the difficulties in financing the proposed upgrading of housing units. However, the lack of consensus on the financial repercussions of maintenance operations severely limited the impact of the model on management decisions. Although the model itself was not used for analysing financial decisions, it did turn the management team's attention to financial aspects and loans, which in the opinion of a number of managers led to the purchase of the Proficon financial package.

## 6.7 Summary

This chapter focused on objective characteristics of context, mechanism and outcome in each of the five cases. The following table presents a summary of the most important characteristics of each case.

| | *City district* | *Ministry of transport* | *Telecommunications provider* | *Housing association East* | *Housing association West* |
|---|---|---|---|---|---|
| **Context** | | | | | |
| *Client organisation* | | | | | |
| Organisation type | governmental/ non-profit/ profit | governmental | profit | profit | profit |
| Sector | services | telecom | telecom | services | services |
| Size | mixed, middle sized city | about 30 employees | 400 employees | about 20 employees | about 20 employees |
| *Problem complexity* | | | | | |
| Analytical complexity | high | high | high | high | high |
| Social complexity | high | high | medium | high | high |
| **Mechanism** | | | | | |
| *Participant characteristics* | | | | | |
| Number of participants | 17 | 10 | 10 | 4 | Phase 1 to 3: 12; 6; 1 |
| Function of participants | managers and staff | staff | managers and staff | managers | managers |
| *Consultant* | | | | | |
| Consultant | Nijmegen University (3) | Nijmegen University (2) | KPN Research (3) coached by Nijmegen University (1) | Atrivé (2) | Atrivé (2) |
| *Duration* | | | | | |
| Time involvement participants | 3 sessions, 11 hours | 4 sessions, 13 hours | 3 sessions, 10 hours | 5 sessions and individual interviews | 6 sessions and individual interviews |
| Approximate project duration | 6 months | 11 months | 2 months | 6 months initial model, 2 months final model | Phase 1 to 3: 6 months; 1 year; 2 months |
| *Techniques employed* | | | | | |
| Techniques employed | NGT in GroupSystems, CLD, workbook | NGT, CLD, workbooks | NGT, flow model, graph estimation, discussion model runs, workbooks, individual interview | Data gathering, CLD, individual interview | Data gathering, CLD, workbooks, individual interview |

| | | | | | |
|---|---|---|---|---|---|
| *Model characteristics* | | | | | |
| Preliminary model | no | no | Qualitative flow model | Quantitative | Quantitative |
| Type of model | Qualitative, small | Qualitative, small | Quantitative, small | Quantitative, large | Quantitative, large |
| **Outcome** | | | | | |
| Conclusions/ dissemination | Written report to higher management level | Written report, internal | Verbal report to higher management level | Flight simulator | Business plan |
| System changes | Implemen-tation | Policy development | No system changes | Annual report, negotiations, implementation | No system changes |

*Table 6.2 Objective context, mechanism and outcome characteristics for cases (NGT refers to Nominal Group Technique, CLD refers to causal loop diagram)*

# Chapter 7 Results

## 7.1 Introduction

### 7.1.1 Overview

The previous chapter described five group model building cases, with a focus on their objective context, mechanism and outcome characteristics. This chapter mainly addresses the subjective characteristics of the five cases. The figure below captures the objective and subjective concepts in this study and their expected relationships.

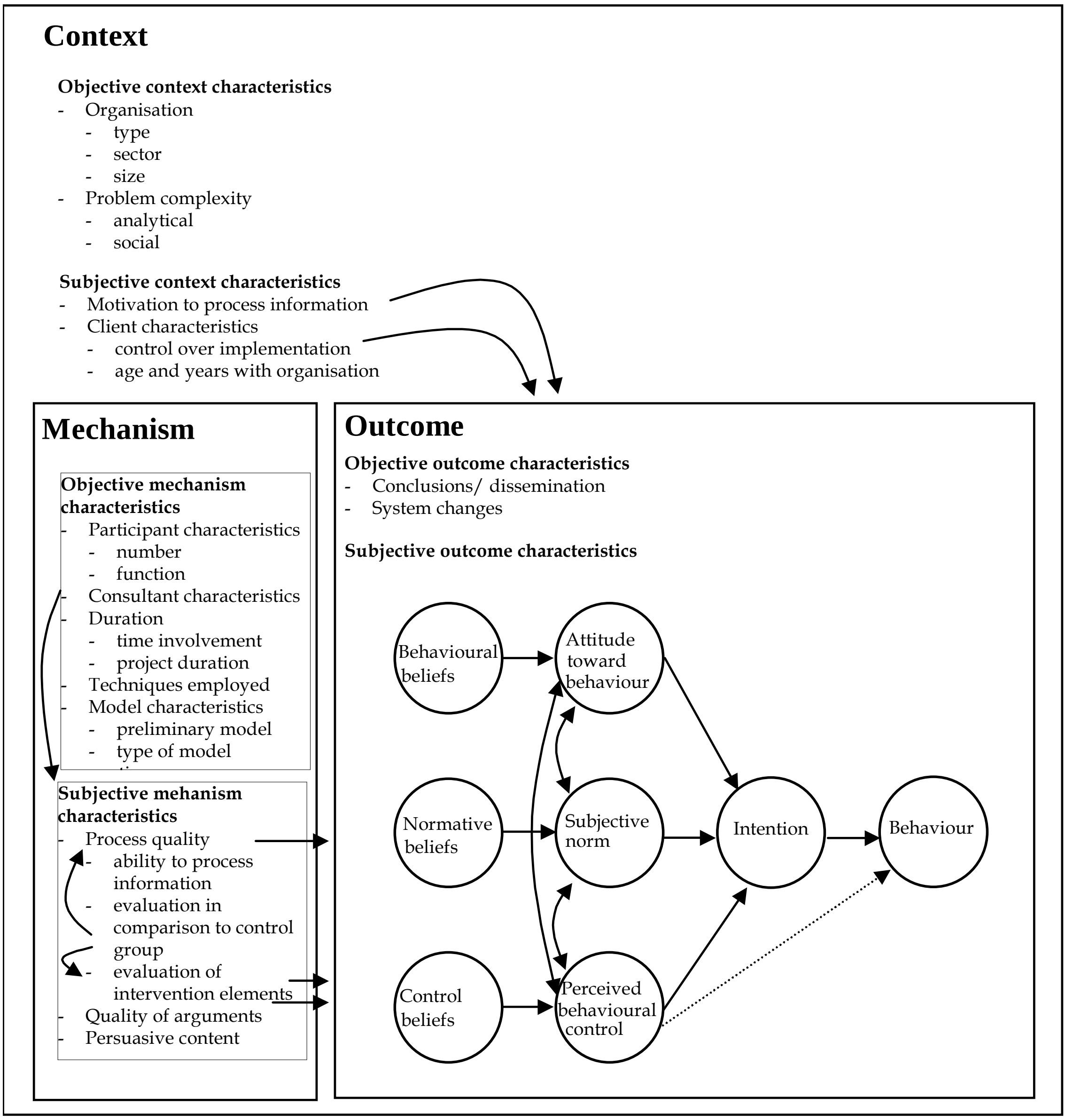


*Figure 7.1 Conceptual model of group model building effects*

Please note that figure 7.1 is still a simplification of the relation between variables. A more complete overview of the variables related to attitudes is depicted in figure 7.2.

Subjective characteristics of the context of group model building are motivation to process information about the problem and client characteristics.
Group model building can be recognised in the figure as the objective mechanism characteristics. Previously two main elements of group model building were considered, i.e. modelling and facilitation. In the last chapter modelling and facilitation were specified further into the specific techniques used in the intervention, model type and size of the model constructed in the sessions. In addition, the intervention was described with regard to participants, consultants and duration. On the basis of these objective characteristics, participants will arrive at a subjective evaluation of the intervention. Participants' evaluations of the intervention are separated into process quality, argument quality and the persuasive content of the information exchanged in the modelling project. Process quality can be further subdivided into ability to process information, evaluation in comparison to a control group, and the relative contribution of intervention elements (e.g. group memory or the facilitator) to overall results.
The final category in the figure concerns the outcome variables. Objective outcomes are the conclusions of the project and the way in which these are disseminated in the client organisation(s), and system changes. Subjective outcome variables are changes in beliefs, evaluations, intentions and actions.

As can be seen in the figure, many separate relationships are to be considered in testing this conceptual model. Ideally path analysis would be used to estimate the strength of each relationship. However, the low number of measurements and the fact that we are interested in establishing relationships between variables at multiple levels, prevent this[32]. Instead variables are related to one another in a stepwise procedure. For each category, variables are first described with regard to means and distribution. Next, relations between variables in the same category are addressed. With regard to for instance context variables, age and years with the organisation are related to motivation to process information. Description of and relations between context variables are addressed in section 7.2. Section 7.3 describes mechanism variables and their interrelationships, while section 7.4 discusses outcome variables and their interrelationships.

After describing variables and relations between variables in a single category, relations between variables in different categories are addressed. The main focus of this study is the influence of treatment (positive versus negative arguments) on outcome variables. In order to test this relationship, outcome variables will be

[32] Multiple level path analysis could be used to overcome this problem, but this approach is at present mainly discussed in a theoretical sense and practical applications are few (Hox, 2002).

regressed on treatment, other mechanism variables, and context variables. Since the Ajzen model (1991) assumes that causation flows from beliefs to evaluations, to intentions and finally to actions, this order is followed here as well. Section 7.5 first goes into the relation of treatment to beliefs, controlling for other mechanism variables as well as context variables. Next, the relation of treatment to evaluations, intentions, and finally behaviour is addressed.
After relating context to mechanism, and mechanism to outcome, the issue of context-mechanism-outcome configurations remains to be addressed. Sections 2.3.6 and 3.6 described how a particular context urges a system dynamicist to choose certain modelling techniques over others. In a very messy problem for instance, a qualitative model is more likely to be chosen than a quantitative model. The combination of a messy problem and a qualitative model in turn influences the outcome of the modelling intervention. The context-mechanism-outcome patterns that were found in section 3.6 are compared to the data of this study in section 7.6. The chapter closes with a short summary in section 7.7.

Many of the results described in this section concern the question: is there a relationship between the information exchanged in group model building and outcome variables? As figure 7.1 illustrates, outcomes cannot be considered in isolation but are related to one another. Consider e.g. the impact of group model building on behavioural beliefs. In chapter 5 the persuasive content of information (whether arguments are positive or negative with regard to a participant's position) was described as the central treatment variable. However, to assess the impact of modelling on behavioural beliefs, persuasive content cannot simply be related to changes in behavioural beliefs. This impact will be mediated by the other variables in the Ajzen model, i.e. normative beliefs and control beliefs. In addition, the impact of other mechanism variables (ability to process and argument quality) and context variables (motivation) needs to be taken into consideration. Before going into a description of variables and relationships, the following section therefore discusses the way in which relations are analysed. In summary, the results of this study are reported in this chapter in the following order.

| *Section* | *Hypotheses* |
|---|---|
| 7.1 introduction | |
| 7.1.1 overview | |
| 7.1.2 analysis method | |
| 7.2 context variables | |
| 7.2.1 description of context variables | hypothesis 1 on motivation to process information |
| 7.2.2 relations between context variables | |
| 7.3 mechanism variables | |
| 7.3.1 description of mechanism variables | hypothesis 2 on process quality<br>hypothesis 3 on argument quality |
| 7.3.2 relations between mechanism variables | |
| 7.4 outcome variables | |
| 7.4.1 description of outcome variables | |
| 7.4.2 relations between outcome variables | |
| 7.5 relation of context, mechanism and outcome | |
| 7.5.1 relation of context and mechanism to beliefs | hypotheses 4, 5 and 6 on beliefs |
| 7.5.2 relation of context and mechanism to evaluations | hypotheses 7, 8 and 9 on evaluations |
| 7.5.3 relation of context and mechanism to intentions | hypothesis 10 on intentions |
| 7.5.4 relation of context and mechanism to behaviour | hypothesis 11 on behaviour |
| 7.6 context – mechanism – outcome configurations | hypotheses 12, 13 and 14 on context – mechanism – outcome configurations |
| 7.7 summary | |

*Table 7.1 Outline of chapter seven*

### 7.1.2 Analysis method

This section describes the analysis method used to estimate variables and relations. The first topic is the analysis of outcome variables: beliefs, evaluations, intentions and behaviour. Hypotheses 4 to 11 propose that the persuasive content of the information exchanged in modelling (positive or negative arguments) are related to changes in outcomes. This boils down to comparing differences between pretest and posttest for two types of outcomes: those receiving positive arguments and those receiving negative arguments. Several alternatives for assessing pretest – posttest differences are available. Vennix (1990: 168) describes two options: using the difference score between pretest and posttest, or alternatively using the posttest score as a dependent and the pretest score as a covariate. Usually the latter method is preferred, especially if variances of variables in pretest and posttest are not equal. Since the intervention is likely to bring about a change in variance, this method is preferable in this study and is used in the following sections. However, difference scores were used as an additional check on results. Apart from the regression analyses reported in the following, difference scores were regressed on pretest score[33], treatment (positive versus negative arguments), context, mechanism and outcome variables. An analysis of the effect of pretest scores constitutes an important test of regression to the mean as noted in section 5.3.2.

In the following sections posttest scores will be regressed on pretest score, treatment (positive versus negative arguments), context, mechanism and outcome variables and correlated error terms. In order to assess whether the data confirm to the assumptions underlying regression analysis the data were tested for normality and equality of variance, independence and linearity. Interaction effects and tests on the assumptions for regression analysis are reported in appendix D. To illustrate the analysis of the relation between persuasive content and outcome variables, the following figure shows the variables related to changes in attitude.

[33] The regression of difference scores on pretest scores points to the same conclusions with regard to hypotheses four to ten as reported in the following. Results of a regression analysis using difference scores are therefore not reported separately.

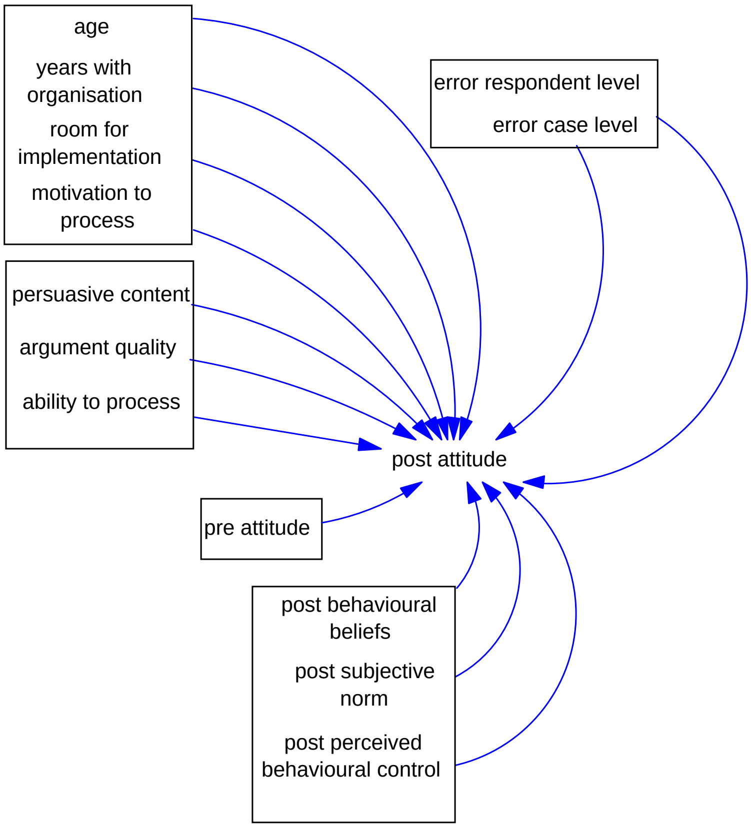


*Figure 7.2 Influences on posttest attitude score*

The influences on attitude, proposed by the conceptual framework shown in figure 7.1, can be separated in five categories. The box at the upper right hand corner shows the error introduced by the different levels of measurement of variables in this study. The relations between mechanism and outcome variables involve three measurement levels:

- behavioural options, e.g. zero tolerance policy in a city neighbourhood;
- respondents, individual participants in a modelling project;
- case, the application of group model building in a specific organisation and problem.

The lowest level is the level of behavioural options, as respondents answer questions on e.g. attitudes with regard to several options. Each option is measured separately in both pretest and posttest and arguments received may be positive with regard to one option, and negative with regard to another. Each respondent therefore has several attitude scores (two to four), where attitude 1 for respondent 1 does not refer to the same attitude object as attitude 1 for respondent 2. In e.g. case 1, attitude 1 for one respondent concerns zero-tolerance policy, while for another respondent attitude 1 is on courses on social skills. It is therefore only meaningful to look at changes from pretest to posttest (comparing scores on the same object), while the overall score of

attitude 1 (averaging over objects) is not interpretable. The separate attitude measurements can be seen as repeated measures for each respondent.
The second level of measurement, the respondent, can be expected to influence the scores on separate behavioural options. Measures for each person can be expected to correlate. In assessing the effects of the treatment variable, a correlated errorterm was therefore included in the regression analyses.
The highest measurement level, the case, can be expected to introduce variance in a similar way. Case effects will be incorporated in estimating regression coefficients by including case dummies in the regression equation.
Going back to figure 7.2, the second box (upper left hand corner) includes the subjective contextual variables: age and years with organisation, control over implementation and motivation to process. Motivation to process was expected to interact with mechanism variables (ability to process, argument quality and persuasive content). In assessing the effect of mechanism variables on attitudes, motivation therefore needs to be included as a covariate.
The third box includes the three mechanism variables: persuasive content, argument quality and ability to process. In the previous chapter the hypothesis was formulated that persuasive content would be related to change in attitudes. However, theories on persuasion (e.g. Petty and Cacioppo, 1986) propose that argument quality mediate the effect of persuasive content. We can therefore expect all of the three mechanism variables to have an effect on outcome variables.
The fifth and last box shows the proximate effects on attitudes in the Ajzen (1991) model. The Ajzen model proposes that distant variables (e.g. persuasive attempts) influence attitudes through their influence on behavioural beliefs. If this proposition is correct, no direct influence of mechanism variables on attitudes will be found if we control for behavioural beliefs. Likewise, the Ajzen model proposes that attitudes are linked to subjective norm and perceived control. Both of these variables are affected by mechanism variables as well (although only indirectly, again through their corresponding beliefs). The effect of mechanism on attitude may therefore be mediated by subjective norm and perceived control. So although the hypothesis on attitude change states that there will be a relation between mechanism and attitude change, the Ajzen model proposes that this will be an indirect relationship which will be mediated by other variables.

The foregoing example showed how the hypothesis on attitudes will be investigated. Analysis of the effect on other outcome variables proceeds in a similar way. For beliefs there are fewer adjacent effects to be considered, as the Ajzen theory proposes that the causal influence proceeds from beliefs to evaluations to intentions, and finally to behaviour. However, the effect of mechanism on a particular set of beliefs will be mediated by the two other sets of beliefs, so these will be considered as covariates as well. For the analysis of changes in subjective norm and perceived behavioural control the same procedure as described for attitudes will be used. In estimating changes in intention, evaluations will be used as covariates. Finally, in estimating changes in behaviour, other variables will be included in a qualitative analysis. No quantitative measurements of behaviour were obtained so the effects of other Ajzen variables on behaviour cannot be estimated quantitatively.

In sum, outcome variables will be assessed on the level of behavioural options, by regressing posttest scores on a pretest scores, treatment (positive versus negative arguments), case effects, context variables, mechanism variables and outcome variables, controlling for correlated error on the level of the respondent. The following section describes context variables.

## 7.2 Context variables

Section 5.4.6 described the contextual factors in this study: organisational characteristics (type, sector and size), problem complexity (social and analytical), motivation to process information and client characteristics (extent to which participants can implement conclusions, age and years working with the organisation). Organisational characteristics and problem complexity were addressed in the last chapter. In this section, motivation to process information and client characteristics are described and related to one another. The expectation is that motivation to process information are high, ensuring that participants are willing to consider all arguments exchanged in the modelling sessions. Room for implementation is also expected to be high, enabling participants to put modelling recommendations into practice. There are no prior expectations about the relation of age and years working with the organisation to other variables. The relations of context variables to one another are reported in section 7.2.1. A full description of context variables is given in appendix D, section 2.

### 7.2.1 Description of context variables

The previous chapter described problem complexity for each case. Following the characteristics used by Hickson et al. (1986) all cases can be described as highly complex problems. This leads to the expectation that all participants will be motivated to process information on the problem, since they will feel the problem is important to them and their organisation. The data to a large extent confirm this. Problem importance scores from 3.90 to 5.00 (on a scale from 1: very unimportant to 5: very important). Problem importance is high and does not show large differences between cases. The degree to which participants find the problem important to their organisation was taken as a measure of motivation to process information (see section 5.5.5). Motivation to process information is high (mean score=4.40, sd=.52). The first hypothesis was formulated as follows.

*1) Participants in group model building are motivated to process information.*

Motivation is significantly higher than neutral (t=15.492, significance=.00), which means that hypothesis one is not rejected.

The extent to which conclusions can be implemented shows a similar pattern. In all cases a high proportion of behavioural options can be implemented (from 67% to 79%). Section 5.4.6 described how system dynamicists gradually concentrated on involving managers with sufficient decision making power in their group modelling efforts (Roberts, 1978; Weil, 1980). Frequently this is taken to indicate that working with line managers is preferred over participants in staff positions. In this study cases are very different with regard to the number of participants in staff or line positions. In case 2 (directorate-general) for instance, all participants work in staff positions, while in case 1 most participants have direct responsibilities in the problem. However, this does not translate to a low proportion of implementable options for case 2. The reason for this is that respondents defined behavioural options that they could (at least partially) control, e.g. by advising on policies in their organisation. Examples are 'formulating conditions for safety in information exchange' or 'allowing more parties on telecommunication market'. So in effect participants in staff positions had a similar control over actions than line managers, because they focussed on a different kind of behavioural options.

The final contextual variables are age and years working with the organisation. These variables do show differences between cases. Respondents in case 4 are relatively older than in case 1, 3 and 5. The average ages for case 1, 3, 4 and 5 are 50 years, 36 years, 59 years and 50 years respectively. In case 2 and 3 participants have been working with their organisation for a shorter period than case 1 and 4 (5 and 6 years versus 14 and 12 years). The following section addresses relations between context factors.

### 7.2.2 Relations between context variables

This section addresses the relations between motivation to process information and client characteristics (room for implementation, age and years working with the organisation). The theories used for constructing the conceptual model for this study (see chapters two and four) do not specify any relations between these variables.

Section 2 of appendix D reports on an analysis of covariance between context variables. Only age and ability to implement conclusions have a significant (positive) relation. Since this does not have important repercussions for the conceptual model in this study, it will not be considered further in the analysis of results.

## 7.3 Mechanism variables

In this section mechanism elements are discussed. Group model building was expected to have a positive effect on both process and content of decision making. Process and content were in turn expected to influence participants' beliefs. In the following mechanism variables are first described separately. Next, the relation between mechanism variables is addressed.

### 7.3.1 Description of mechanism variables

Mechanism variables were divided into process and argument quality. Process quality was further subdivided into ability to process information, evaluation of process elements and evaluation in comparison to a control group. Each of these variables is discussed below.

*Ability to process information*

With regard to ability to process information, quantitative as well as qualitative (interview) data were gathered. For the quantitative measurement, a scale was developed consisting of six Likert items (see section 5.5.4) measured from 1: strongly disagree to 5: strongly agree. The overall score on this scale is 3.85 (n=34, min=2.83, max=5.00, sd=.50) This score is significantly higher than neutral (t=10.006, one-sided significance=.000). The following table shows the results for the separate aspects of ability to process information.

| *Aspect* | *n* | *min* | *max* | *mean* | *sd* |
|---|---|---|---|---|---|
| open communication | 34 | 2.00 | 5.00 | 4.06 | .69 |
| clear and understandable communication | 33 | 2.00 | 5.00 | 3.82 | .73 |
| everybody had a chance to voice their opinion | 33 | 3.00 | 5.00 | 4.03 | .53 |
| ample opportunity to raise issues about which opinions diverged | 33 | 2.00 | 5.00 | 3.64 | .86 |
| a focussed approach | 33 | 2.00 | 5.00 | 3.70 | .85 |
| attention to each others' ideas | 33 | 2.00 | 5.00 | 3.85 | .62 |

*Table 7.2 Participants' opinions on aspects of ability to process information*

The mean score of each of the process aspects is above neutral. Two additional questions deal with overall success and efficiency of group model building. On average, participants feel the modelling project was successful (mean score 3.69, n=32, min=2.00, max=5.00, sd=.69). Efficiency scores are satisfactory as well (mean score 3.76, n=29, min=2.00, max=5.00, sd=.83).

The interviews a included a couple of questions which can help in interpreting these results. Three interview questions are relevant to ability to process information. First, the interviews indicate that participants knew most of the other attendants (on average 83% of all participants, n=19, min=25%, max=100%). In general participants had met and cooperated with the other participants on previous occasions, and this cooperation was in general satisfactory. Few participants had been in conflict with one another[34].

Second, interviewees in general have no particular prior expectations of the sessions. A few participants have previously worked with models of a different type than system dynamics, and this influences their expectations. Some of these participants expect a very rational approach based on exact numbers, and are (pleasantly) surprised to see that the actual approach in the sessions is different.

Third, participants are asked to indicate what event related to the sessions stood out in their memory. This question evokes reactions with regard to the content as well as the process of the sessions. On the level of content, interviewees state that the problem was known to them, although specific consequences of the problem were new and the model provides an overview that was not present previously. Participants appreciate the integrated view offered by the model, and frequently conclude that the problem is more urgent and broader than expected. The remarks on process corroborate this: participants value the ability of the approach to create a consensus view and to combine ideas from divergent points of view. A small number of participants mentions that group model building encourages people to have an active contribution to the process. The interview data substantiate the high score on open communication and ability to contribute to the discussion as indicated by the table above. In addition, the low score of the item 'opportunity to raise issues about which opinions diverged' is partially explained by the fact that there were few highly debated issues. After all, participants knew one another and there were few conflicts. In conclusion, the data indicate that group model building results in a high ability to process information.

[34] The low level of conflict between participants seems to contradict the medium to high level of social complexity in each of the cases, as reported in chapter six. However, please recall that social complexity refers to differences between stakeholders, who are not all present during the modelling sessions. In addition, the interview questions seem to evoke answers with regard to (open) conflictual behaviour, while social complexity refers to differences in interests which frequently is more covert.

*Evaluation of process elements*

A further question with regard to process quality, is how the separate session elements contribute to the overall effect of the sessions. The following table shows the results for the various elements of group model building. Please recall that elements could be scored from –5 (obstructed the sessions) to 5 (contributed very much to the sessions).

| *Element* | *n* | *min* | *max* | *mean* | *sd* |
|---|---|---|---|---|---|
| projection of diagrams | 32 | .00 | 5.00 | 3.97 | 1.28 |
| presence of a facilitator | 32 | .00 | 5.00 | 3.66 | 1.77 |
| opportunity for open discussion | 33 | .00 | 5.00 | 3.70 | 1.38 |
| causal loop diagrams | 32 | .00 | 5.00 | 3.22 | 1.70 |
| parameter estimation | 8 | .00 | 5.00 | 2.88 | 1.73 |
| model analysis | 5 | 3.00 | 5.00 | 4.20 | 1.10 |
| data analysis | 9 | -3.00 | 5.00 | 1.56 | 2.35 |
| analysis of model output | 8 | -3.00 | 5.00 | 2.63 | 2.72 |

*Table 7.3 Participants' opinions on modelling elements*

From the table it appears that all elements score rather high. Model analysis and the projection of diagrams (the group memory) contributed most to the overall effect of the sessions. Two other important elements of the intervention, opportunity for open discussion and presence of a facilitator, have the next highest scores. Data analysis receives the lowest score.

*Evaluation in comparison to a control group*

The last element of process quality is the comparison of group model building to regular meetings. In the last section of the posttest questionnaire, participants were asked to compare the modelling sessions to regular meetings. These questions could be answered on a scale from 1 (strongly disagree) to 5 (strongly agree).

| *Comparison* | *n* | *min* | *max* | *mean* | *sd* |
|---|---|---|---|---|---|
| more insight | 31 | 3.00 | 5.00 | 3.84 | .52 |
| faster insight | 30 | 2.00 | 5.00 | 3.53 | .82 |
| better communication | 30 | 2.00 | 5.00 | 3.57 | .63 |
| faster consensus | 31 | 2.00 | 5.00 | 3.68 | .83 |
| more clear consensus | 31 | 2.00 | 5.00 | 3.77 | .62 |
| faster commitment | 30 | 2.00 | 5.00 | 3.37 | .77 |
| more commitment | 31 | 2.00 | 5.00 | 3.55 | .77 |

*Table 7.4 Participants' opinions on quality of sessions compared to regular meetings*

All scores are above neutral, indicating that modelling sessions are indeed considered more effective on these aspects than regular meetings. The difference from neutral is significant for all items (for faster commitment one-sided significance .007, for other items .000). Two outcomes are similar to other modelling cases reported by Vennix and Rouwette (2000). First, the highest score is obtained for increased insight. Second, the questions on the 'speed' of obtaining an effect on average score lower than the 'magnitude' of the effect (e.g. more commitment scores higher than faster commitment).

The results with regard to ability to process information and comparison to a control group, provide an answer to hypothesis two. Hypothesis two was formulated as follows.

2) *Group model building leads to a high quality decision making process, i.e.*
   a. *high ability to process information;*
   b. *positive evaluation compared to traditional meetings.*

The score on the process quality scale and on the separate comparisons to a control group indicate that the second hypothesis is not rejected. After having discussed the three elements of process quality, the discussion now turns to argument quality.

*Argument quality*

In the following, first questionnaire data are discussed, followed by the interview data. Argument quality is measured using a scale of nine Likert items, which could be scored from 1 (strongly disagree) to 5 (strongly agree). An example is 'In the meetings all relevant risks were discussed'. Section 5.5.4 describes the analysis of the scale and shows how the item on costs does not correlate to the total scale. The item on costs scores below neutral (mean=2.61, n=31, min=1.00, max=4.00, sd=1.02). The overall score on this scale is 3.24 (n=33, min=2.00, max=4.22, sd=.51) This score is significantly higher than neutral (t=2.662, one-sided significance .01). The following table shows the results for the separate dimensions of outcome quality.

| *Dimension* | *n* | *min* | *max* | *mean* | *sd* |
|---|---|---|---|---|---|
| all relevant options | 32 | 2.00 | 5.00 | 3.44 | 1.05 |
| all relevant goals | 32 | 2.00 | 5.00 | 3.50 | .88 |
| all relevant values | 31 | 2.00 | 5.00 | 3.55 | .85 |
| all relevant risks | 33 | 1.00 | 5.00 | 2.76 | 1.00 |
| all relevant information for weighing options | 31 | 2.00 | 4.00 | 3.06 | .81 |
| all relevant information is integrated | 30 | 2.00 | 5.00 | 3.60 | .81 |
| all positive and negative consequences | 27 | 2.00 | 4.00 | 3.26 | .66 |
| all relevant conditions | 31 | 1.00 | 4.00 | 3.16 | .86 |
| all relevant contingencies | 27 | 1.00 | 4.00 | 2.85 | .82 |

*Table 7.5 Participants' opinions on dimensions of argument quality*

As we can see from the table, participants in general agree that all goals, values and consequences have been discussed, and that all information is integrated. They do not feel that all risks and contingencies have been dealt with. Other elements (options, information for weighing options, conditions) score around neutral. In section 5.4.2 on the expected direction of change, it was indicated that only four out of 86 actions do not correspond to a model variable or recommendation. It seems that most of the actions that participants (in the posttest) list as relevant to the problem are addressed in the sessions, but the question whether all relevant actions are addressed scores around neutral (3.44 in the table above). In the interviews several respondents state that the most relevant actions have indeed been identified, but that a comprehensive treatment of all possible actions would be impossible. In general the questionnaire data indicate a positive evaluation of arguments exchanged in the sessions.

The interviews offer more specific insights into the information exchanged in the modelling process. Several interview questions are relevant to this issue:

- did the sessions provide information relevant to your work?
- are the changes from pretest to posttest recognisable?
- are the changes from pretest to posttest due to the sessions or to other developments?

In general participants answer negatively to the first question. Most respondents state that all relevant information was known to them, although the sessions did integrate the most relevant information and allowed to see the interrelations between important topics. As described above, when participants are asked about events in the sessions that stood out in their memory they say they learned nothing new although both specific examples and the overview offered by the model are new. Strangely enough however, if they are confronted with the changes between pretest and posttest most respondents find these recognisable, indicating that a change in evaluations has taken place. In other words, respondents have received relevant information during the sessions but initially do not seem to be aware of this. It seems as if there are three levels at which information is considered: 1. the 'medium' level at which the problem is usually considered, in which the most important elements of the problem are represented, 2. a more detailed level that contains specific examples of processes and 3. the general level in which the relation between various elements is considered.

In a small subset of the interviews respondents were asked how they thought the observed changes in evaluation (attitude, norm or control) came about: through information received during the sessions or information gained outside of the modelling project. This topic is also important with regard to the first threat of validity discussed in 5.3.2: history. A total of 19 observed evaluation changes are discussed with participants, of which five are contributed to the sessions[35]. This outcome is difficult to interpret, as sometimes developments in the own organisation work contrary to the information gained in the sessions (see the examples in the previous section) and posttest evaluations will show the integration of both influences[36]. However, most participants point to either the sessions or developments in the problem to explain changes in their evaluation. In conclusion, it seems questionable to which degree participants are able to assess a. the extent to which they changed opinions and evaluations over a time period and b. the cause of this change. The effect of history on changes in outcomes can therefore not be ruled out completely.

So far actions which were identified in the pretest were discussed. However, since the information exchanged in the sessions has unanticipated effects, other actions

[35] There are two to four evaluations for each of 74 options, or a total of 258 evaluations. Of the total number, 157 change from pretest to posttest. Since in a number of cases the time available for interviews was limited, changes in evaluations were addressed in only in a limited subset of the interviews. A total of 19 changes are discussed with respondents; in five instances respondents point to information received in the sessions as the reason for evaluation change.

[36] In addition one respondent pointed out that she changed her evaluation not so much because of the information exchanged in the sessions (which was positive with regard to this issue) but because of the general negative *tone* of the discussion. This issue will be discussed further in chapter eight.

than those mentioned in the pretest may be affected as well. It is likely that the information in the sessions has a wider impact on participants' actions.

On the basis of the answers to the questionnaire and interview items, hypothesis three can be answered. Because of the difficulties associated with participants' self-assessment of changes in insight, mainly the quantitative (questionnaire) data will be used to test hypothesis three. The interview data support the questionnaire data in the sense that participants do not reject the observed evaluation changes from pretest to posttest. In only a minority of cases evaluation changes are contributed to information gained during modelling, but it was shown that self-estimation of the reason for evaluation change is difficult. The third hypothesis was formulated as follows.

3) *In group model building arguments for evaluation change are exchanged.*

Since the score on the scale of argument quality is significantly higher than neutral, hypothesis three is not rejected. After having discussed process and argument quality separately, the following section goes into relations between mechanism variables.

### 7.3.2 Relations between mechanism variables

The mechanism variables that were described in the foregoing section operate at two levels of abstraction. Ability to process information and argument quality are characteristics of the group model building process in its totality. In order to assess e.g. ability to process information, participants will have to average over all sessions in the modelling project. Process elements, on the other hand, are formulated at a more specific level. Participants are asked to disaggregate the model building process in order to evaluate the relative effectiveness of e.g. the facilitator or the use of causal loop diagrams. The evaluation of the contribution of specific elements provides more specific information on what works and what does not work in group model building. This section therefore addresses the following question: how do the separate element scores relate to overall mechanism scores (ability to process information and argument quality)?[37]

[37] A second question related to modelling elements is on the relation between separate modelling elements and modelling outcomes (e.g. beliefs). This question goes beyond relations between mechanism elements and will therefore not be addressed in this section. Section five of appendix D shows the results of a regression of outcome variables on mechanism elements.

In analysing the relation between mechanism elements and overall mechanism scores, the following variables will be included. Mechanism elements that are relevant to the quantitative modelling cases (parameter estimation, analysis of the model, analysis of data and simulation of the model) are only measured in a subset of the modelling cases. Analysis of data and simulation were only included in case 4 and 5, while parameter estimation and model analysis were included in case 3. For all of these variables a regression model including pretest and treatment effects cannot be specified. Therefore these variables will not be included in the analysis. Mechanism elements that were present in both qualitative and quantitative modelling cases are the following: projection of diagrams, presence of a facilitator, opportunity for open discussion and use of causal loop diagrams.
As can be seen in figure 7.1, the conceptual model does not include the assumption that relations between mechanism variables will be moderated by context variables, e.g. age or motivation to process information. Therefore the effect of mechanism elements on overall mechanism scores will be assessed by regressing the dependent scores on the mechanism elements specified above. The following table shows the outcomes of the regression analysis.

| | $\beta_0$ | $\beta_1$ projection | $\beta_2$ facilitator | $\beta_3$ discussion | $\beta_4$ diagrams | $R^2$ | n |
|---|---|---|---|---|---|---|---|
| Ability to process information | 3.01 (.30) | .13 (.10) | -.02 (.06) | .11 (.09) | .01 (.06) | .29 | 29 |
| Argument quality | 2.84 (.36) | .31 (.14)* | -.13 (.08) | -.04 (.11) | -.07 (.07) | .19 | 28 |

*Table 7.6 Multiple regression of overall mechanism scores on mechanism elements (cells contain beta coefficients and standard error), * significant at the .05 level*

As can be seen from the table, mechanism variables explain very little variance of overall process scores. The only significant effect is from projection of diagrams on argument quality. Other mechanism elements do not significantly predict overall mechanism scores. This concludes the discussion of mechanism variables. The following section addresses outcomes.

## 7.4 Outcome variables

In this section outcome variables, i.e. beliefs, evaluations, intentions and behaviour, are discussed. Again variables are first described, after which relations between outcomes are addressed. The description of variables concentrates on changes from pretest to posttest. In discussing changes, outcome variables receiving positive arguments are distinguished from those receiving negative arguments. In the third case, for instance, one of the options to alleviate the problem is 'frustrating monopolist service providers'. Analysis of the model constructed in this case clearly shows negative outcomes of this option. Behavioural beliefs, which reflect the participant's ideas on the outcomes of this option, are thus expected to change in a negative direction over the course of the modelling sessions. Likewise, a number of options receive positive information and are therefore expected to be evaluated more positively from pretest to posttest. By contrasting options receiving negative and positive information, a first insight into the effect of information exchanged in the sessions is obtained.

Next, the relation between outcome variables is addressed. This will be done by describing relations between beliefs, evaluations and intentions, in both pretest and the posttest. Relations are addressed in a quantitative analysis (correlation and regression) and in a qualitative test, by asking respondents in the study about their opinions on the expected relations.

### 7.4.1 Description of outcome variables

In this section changes in beliefs, evaluations, intentions and behaviour are described. Further details on these changes can be found in appendix D, section 4. Section 7.5 addresses the significance of changes and the relation to context and mechanism variables.

*Beliefs*

This section focuses on changes in beliefs from pretest to posttest. The following figure visualises the changes from pretest to posttest. Please note that beliefs are calculated by combining belief strength (scale –5 to +5) and evaluation of the outcome (scale 1 to 5) as described in section 5.4.3.

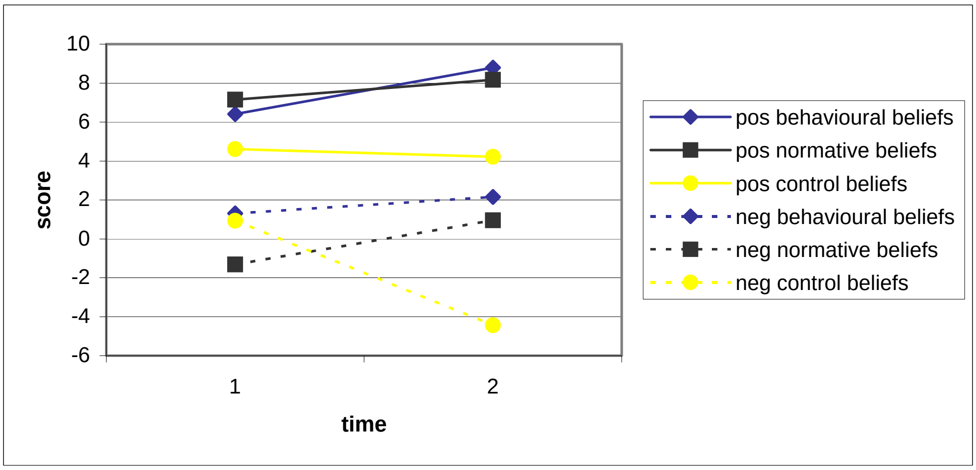


*Figure 7.3 Mean pretest and posttest scores for beliefs receiving positive arguments (straight lines) and negative arguments (dotted lines)*

As mentioned before, beliefs receiving positive information are expected to become more positive from pretest to posttest. Beliefs receiving negative information are expected to become more negative from pretest to posttest. Three changes do not correspond to expectations: the score on control beliefs that receive positive information tends to become lower, while the mean score on behavioural and normative beliefs receiving negative information increases from pretest to posttest. A discussion of the significance of these changes and possible explanations will be postponed to section 7.5.
With regard to normative beliefs, additional information was obtained in a number of open questions. Respondents were asked about important referents with regard to the problem in question (cf. Felling, 1974), which form the basis for normative beliefs. The answers confirm the expectation that the participant group contains a number of important referents. We can therefore expect that a person's normative beliefs will be influenced by the opinions of other participants in the sessions, which will be further explored in section 7.5.

*Evaluations*
The following figure shows pretest and posttest scores for evaluations receiving positive arguments and evaluations receiving negative arguments.

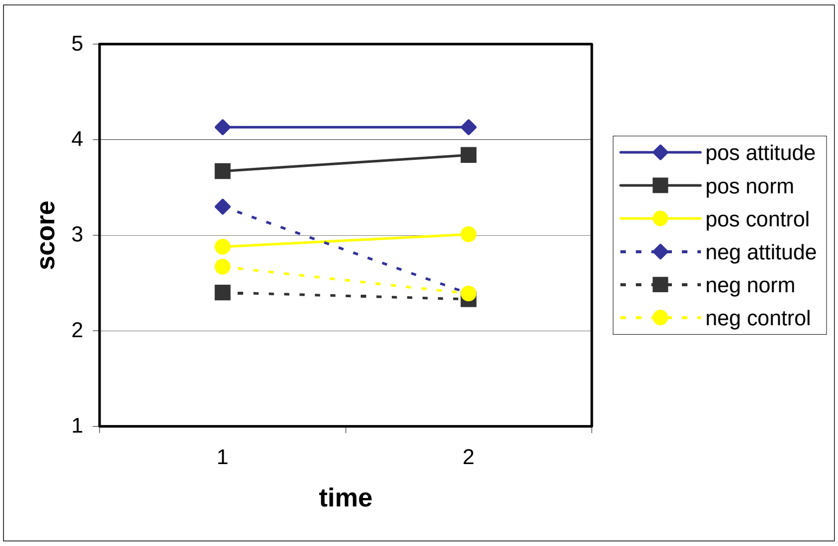


*Figure 7.4 Mean pretest and posttest scores for evaluations receiving positive arguments (straight lines) and negative arguments (dotted lines)*

As can be seen from the figure, evaluations receiving positive arguments do not show large changes from pretest to posttest. Attitude remains unchanged, subjective norm and perceived control show a small increase. Evaluations receiving negative arguments tend to decrease. The largest change from pretest to posttest is found for attitudes receiving negative arguments.

*Intentions and behaviour*

This section addresses changes in intentions and behaviour from pretest to posttest. Please recall that for intentions the expected direction of change is determined by selecting the categories of change for which attitudes, norm and control change in a similar direction. For example if both attitudes, norm and control are expected to change in a negative direction, intention is expected to decrease as well. In this way the number of actions for which the change in intentions can be determined is smaller than for the other variables in the Ajzen model. For 64 behavioural options the expected direction of change for intention can be assessed, while for 62 measurements both pretest and posttest scores are obtained. Changes in intention scores on the individual level are as follows: 27.4% shows a decrease from pretest to posttest, 48.4% remains unchanged and 24.2% shows an increase.

With regard to behaviour, qualitative assessments were obtained. Interviews with the gatekeepers were held several months after the modelling projects, in order to determine which kind of follow-up was given to the recommendations of the project. The previous chapter presented a number of changes in behaviour which can be related to the group model building interventions. However, variables outside of the modelling intervention had a large impact on behavioural changes as well. In e.g. the third case the model provided useful insights which would be analysed in a further modelling effort. However, changes in the telecommunications market presented more urgent problems and drew attention away from the model. Therefore a full treatment of the impact of modelling on behaviour will be postponed to the section on relations between context, mechanism and outcome. After describing outcome variables, the following section addresses relations between outcomes.

### 7.4.2 Relations between outcome variables

This section describes the relations between outcomes: beliefs, evaluations, intentions and behaviour. The expected relations between these variables are specified by the theory of planned behaviour (Ajzen, 1991) which was described in section 4.3.2. Figure 7.1 shows that beliefs are expected to impact evaluations (attitude, subjective norm and perceived behavioural control) and evaluations in turn affect intentions. Perceived behavioural control and intentions are expected to determine behaviour. Section 4.3.2 also described a number of domains to which the theory of planned behaviour has been applied previously, for instance losing weight, job search, and getting an 'A' in a course. Its seems useful to look into the relations between variables in the Ajzen theory for a couple of reasons. Few applications of the model to organisational behaviour can be found. Van den Putte (1993) points out that for describing particular behaviours, adaptations of Ajzen's model might be necessary. Testing to which extent the expected relations are found in the domain of this study is also important because it checks an important assumption that can be found in the system dynamics literature, i.e. that modelling goals are related. For example, the expectation is that modelling does not influence implementation directly, but through learning about the problem and creation of a consensus view (see section 2.5.6).

In this section the relations between the variables in the Ajzen model is described by looking at measures employed in traditional attitude research (regression analysis) and a qualitative measure proposed by evaluation researchers (Pawson and Tilley, 1997). Van den Putte (1993) and Ajzen (1991) employ the following quantitative tests for the model's sufficiency:

- a regression of intention on attitude towards behaviour, subjective norm and perceived behavioural control;
- a regression of attitude, subjective norm and perceived behavioural control on beliefs.

In the following, quantitative measures are described first. Appendix D, section 5 provides further details on the results of both regression analyses. Next I turn to the qualitative measure used in evaluation research.

*Regression of intention on attitude, norm and perceived control*

The first test of the relations in the Ajzen model applied to group model building interventions is the prediction of intention by attitude, subjective norm and perceived behavioural control. Attitude, subjective norm and perceived behavioural control were entered in the regression equation in that sequence. In both pretest and posttest, attitude is a significant predictor of intention. Attitude and subjective norm correlate highly with intention and with each other. Perceived control correlates with subjective norm and intention. In combination, the predictive power of attitude, subjective norm and perceived control is significant (pretest $R^2$=.53, posttest $R^2$=.71). However, only attitude and subjective norm are significant independent predictors. Perceived control does not need to be included to explain pretest or posttest scores. Differences between pretest and posttest relations are the following: explained variance increase from pretest to posttest, and in the posttest perceived control and attitude are significantly correlated.

On the basis of both pretest and posttest scores, intention seems to be significantly predicted by attitude and subjective norm. Ajzen's addition of perceived behavioural control to the theory of reasoned action does not seem to be necessary to explain behavioural intentions related to group model building. From the prediction of intention by attitude, subjective norm and perceived behavioural control, we can conclude that the theory of planned behaviour offers a sufficient explanation of intentions in this domain but the inclusion of the variable perceived control is not necessary.

*Regression of attitude, norm and perceived behavioural control on beliefs*

The second test of the relation between outcome variables, is a regression of evaluations on corresponding beliefs. The analysis shows that control, normative and behavioural beliefs are correlated and the relations between belief-based and semantic differential measures are weak. This corresponds to other findings in the literature. Ajzen (1991: 195) points out that correlations between semantic differential and belief-based measures of evaluations are usually of only moderate magnitude. Taking results of both pretest and posttest into consideration, it seems that the measurement procedure followed here results in highly intercorrelated beliefs that relate only weakly to evaluations. Only for subjective norm belief-based and semantic differential measurements are related in both pretest and posttest. Attitude and perceived behavioural control are significantly related in the posttest, but in the pretest attitude is not significantly related to behavioural beliefs and perceived control has a weak negative relation to control beliefs.

A possible solution to the weak relations of beliefs and corresponding beliefs, would be to determine the relevant categories of beliefs by using factor analysis. However, since many beliefs are scored by only one or a few participants, the result of a factor analysis is not meaningful. Therefore the belief based measurements will still be used in the analysis of results, even if measurements are highly intercorrelated and behavioural and control beliefs have weak relations to evaluations. Beliefs and evaluations can therefore best be considered independently in the analysis of results. This does not have consequences for the hypotheses (in which beliefs and evaluations are considered separately) but in reporting mechanism – outcome relations both sets of variables should be treated independently as well.

After the measures for completeness of the Ajzen model used in traditional attitude research, I now turn to a more qualitative measure proposed by evaluation researchers.

*A qualitative measure for completeness of the model*

An alternative measure of the relations specified by the Ajzen model is described by Pawson and Tilley (1997). They propose to confront respondents with the research model and ask for comments. In the interviews after the modelling sessions, the research model was shown to participants, who were then asked whether the variables in the model could explain their behaviour in the problem addressed in the sessions. In general, respondents in this study recognise the variables in the model and think each of these is important in deciding how to react to a problem. Some participants propose additions to the model, that in general boil down to the subjective nature of the Ajzen variables. Four additions are proposed in the interviews: a. all variables are subjective estimations, b. participants will take reactions of other stakeholders into consideration, c. the individual's task in an organisation limits the number of actions that will be considered and d. action alternatives in a problem are only considered if a problem is sufficiently urgent with regard to other problems. The first two considerations are addressed by the Ajzen model in at least a basic fashion, and do not really constitute additions to the model. The third and fourth remarks place boundaries on the actions that are considered by individuals. Since in this study participants are encouraged to consider actions that are at least partially under their control, this does not point to changes to the conceptual model either. However, in considering the applicability of the Ajzen model to organisational decision making, this point needs to be taken into consideration. What is striking, is that the additions to the Ajzen model proposed in the literature (habit and perceived moral obligation), are not mentioned by participants.

Considering the quantitative as well as qualitative results with regard to the relations proposed by the Ajzen model, I conclude that there are no major objections against using the model for estimating impacts of group model building on individual actions.

This concludes the discussion of relations between outcome variables, and with that the relations between variables within separate categories. The following section addresses relations between variables in different categories, or put differently, the way in which context and mechanism variables shape outcomes of group model building.

## 7.5 Relation of context, mechanism and outcome

So far the discussion in this chapter has treated context, mechanism and outcome in isolation. Variables were described and related for each category separately. This section addresses the following question: how do context and mechanism of group model building combine to influence modelling outcomes? The main mechanism variable was described as the persuasive information exchanged over the course of the modelling sessions: participants receive positive or negative arguments with regard to their positions in the problem. On the basis of this information, they are expected to change their beliefs, evaluations, intentions and behaviour in the problem. The impact of information on these outcomes is moderated by the other mechanism variables, such as ability to process arguments and argument quality. In addition, context variables such as motivation to process information and extent to which conclusions can be implemented play a role as well. In the previous sections we have seen that participants are motivated and able to process information, and feel the quality of arguments exchanged is high.

As described in section 7.1.2 outcomes will be regressed on context variables, mechanism variables and related outcomes. The analysis is best explained with regard to a concrete example. For analysing the relation of context and mechanism variables to changes in attitudes, the following steps will be taken. First posttest attitude will be regressed on all independent factors (see figure 7.2):

- correlated error on the level of the individual respondent;
- pretest attitude score;
- treatment (positive versus negative arguments);
- case effects;
- related outcome variables, with regard to attitudes these are behavioural beliefs, subjective norm and perceived behavioural control;
- context variables: ability to implement conclusions and motivation[38];

[38] The variables age and years with organisation will not be considered in the analyses in this section. Only few respondents provided data on either or both of these variables, so that listwise deletion of cases would reduce the number of measurements too far. Section 2 of appendix D describes the relation of age and years with organisation to mechanism and outcome variables.

- mechanism variables other than treatment: ability to process information and argument quality;
- interaction of motivation, ability to process information and argument quality.

The last term is added to the regression equation because the theories on persuasion (section 4.4) propose that people will consider information to the extent that they are able and motivated to do so. Further, if people consider information, the persuasiveness of this information is dependent on the quality of arguments. If arguments are of low quality, e.g. because they are not relevant to the issue at stake, information will not have a persuasive effect. Therefore the impact of persuasive content of information (negative versus positive arguments) is influenced by both motivation, ability and argument quality and their interaction will be included in the analysis of outcomes. The multiple level analysis is performed using MlwiN (Rasbash et al., 2000).

After regressing posttest scores on all factors as described above, in a second step insignificant factors will be removed from the analysis. Case effects, pretest score and correlated error on the level of the individual will be retained as these are covariates. Since listwise deletion is used in this analysis, removal of insignificant variables enlarges the number of cases that can be used in the analysis. In the interpretation of results this needs to be taken into consideration.

For evaluations and intentions, a third analysis will be performed in which indirect effects are tested. With regard to evaluations, this step will address whether evaluations are influenced directly or through beliefs. Likewise, for intentions it will be tested whether these are directly influenced or through evaluations. Attitude, for instance, will first be regressed on all context, mechanism and related outcome variables (step 1), and subsequently on significant factors only (step 2). In the third step, behavioural beliefs will be removed from the regression analysis. In this way the extent to which behavioural beliefs act as an intervening variable in the relation between treatment and attitude, can be deduced.

The results of the second and third analyses will be used to test the hypotheses on the impact of persuasive content on outcomes. In the following beliefs, evaluations, intentions and behaviour will be addressed in turn.

### 7.5.1 Relation of context and mechanism to beliefs

In this section the relation of context and mechanism variables to beliefs are described. As discussed in the previous section, beliefs will first be regressed on correlated error on the level of the individual, pretest scores, case effects, related outcome variables, context and mechanism variables. The result of a regression on all dependent variables is reported in section 6 of appendix D. After the first analysis in which all variables in the conceptual model are included, in the second analysis only significant factors are considered. The result of this regression analysis is reported in the following table.

| *Posttest* | $\beta_0$ | $\beta_1$ *Pretest* | $\beta_2$ *Treatment* | $\beta_3$ *case 1* | $\beta_4$ *case 2* | $\beta_5$ *case 3* | $\beta_6$ *case 4* |
|---|---|---|---|---|---|---|---|
| behavioural beliefs | -.06 (.25) | .35 (.10) | | .68 (.30) | -.68 (.34) | .33 (.31) | -.34 (.36) |
| normative beliefs | -.20 (.43) | .43 (.11) | | -.10 (.50) | -.36 (.54) | .57 (.52) | -.03 (.61) |
| control beliefs | -.72 (.46) | .62 (.12) | .69 (.33) | .04 (.34) | .15 (.46) | .21 (.35) | .36 (.41) |

| *Posttest* | $\beta_7$ *Control beliefs* | $\beta_8$ *Implementation* | $u_{oj}$ | $e_{0ij}$ | *n* |
|---|---|---|---|---|---|
| behavioural beliefs | .13 (.07) | | .15 (.06) | .12 (.03) | 67 |
| normative beliefs | | .29 (.14) | .49 (.15) | .15 (.03) | 67 |
| control beliefs | | | .12 (.08) | .34 (.08) | 67 |

*Table 7.7 Multiple regression of posttest beliefs on correlated error, pretest score, case effects, significant outcome, context and mechanism variables (cells contain beta coefficients and standard error)*

Please note that in this and other tables, in assigning case dummies case 5 is chosen as the reference point. So for instance $\beta_3$ refers to the difference in beta coefficient for case 1 as compared to case 5. Results are reported for a free error term at the respondent and option level. As can be seen from the table, the effect of context and mechanism on beliefs is limited. Ability to implement conclusions is a significant predictor of normative beliefs. Only one relation between beliefs is significant: control beliefs is a significant predictor of behavioural beliefs. This allows us to answer the hypotheses on beliefs.

4) *Participants in group model building change their behavioural beliefs about actions in the problem in the direction of conclusions of the modelling project.*

Since the results indicate that treatment has no significant effect on posttest behavioural beliefs, hypothesis four is rejected. The hypothesis on normative beliefs was the following.

5) *Participants in group model building change their normative beliefs about actions in the problem in the direction of conclusions of the modelling project.*

With regard to normative beliefs, qualitative as well as quantitative data were gathered. Section 7.4.1 reported that participants feel important referents are present in the sessions. This would lead us to expect that normative beliefs (which are based on beliefs of important referents) would change in the modelling sessions. However, on the basis of the quantitative data reported in table 7.16 has to be concluded that normative beliefs are not influenced by the information exchanged in group model building. This suggests that although important referents were present in the sessions, they did not voice unexpected or new opinions on preferred actions. Hypothesis five is rejected. The following hypothesis addresses control beliefs.

6) *Participants in group model building change their control beliefs about actions in the problem in the direction of conclusions of the modelling project.*

Since the results indicate that treatment has a significant effect on posttest control beliefs, hypothesis six is not rejected. Control beliefs are thus the only belief category which is influenced in modelling.
The following section addresses the relation of context and mechanism to the next set of outcomes, i.e. evaluations.

### 7.5.2 Relation of context and mechanism to evaluations

Similar to the analysis of beliefs, evaluations will first be regressed on correlated error on the level of the individual, pretest scores, case effects, related outcome variables, context and mechanism variables. The result of the regression on all independent factors is again reported in section 6 of appendix D. The following table shows the result of a regression of posttest scores of attitude, subjective norm and perceived behavioural control on significant independent variables.

| Posttest | $\beta_0$ | $\beta_1$ Pretest | $\beta_2$ Treatment | $\beta_3$ case 1 | $\beta_4$ case 2 | $\beta_5$ case 3 | $\beta_6$ case 4 |
|---|---|---|---|---|---|---|---|
| attitude | -1.10 (.25) | .34 (.08) | 1.04 (.24) | .21 (.23) | .35 (.25) | .45 (.25) | -.27 (.27) |
| subjective norm | -.06 (.32) | .44 (.10) | .67 (.25) | -.48 (.33) | -.65 (.33) | -.47 (.34) | -1.02 (.37) |
| perceived control | .90 (.32) | .12 (.11) | | -1.04 (.39) | -1.13 (.40) | -1.24 (.43) | -.42 (.48) |

| Posttest | $\beta_7$ Beliefs | $\beta_8$ Attitude | $\beta_9$ Subjective norm | $u_{oj}$ | $e_{0ij}$ | $n$ |
|---|---|---|---|---|---|---|
| attitude | | | .24 (.09) | .00 (.00) | .30 (.05) | 69 |
| subjective norm | .24 (.12) | | | .09 (.07) | .33 (.07) | 70 |
| perceived control | | .47 (.12) | | .10 (.11) | .60 (.13) | 69 |

*Table 7.8 Multiple regression of posttest evaluations on correlated error, pretest score, case effects, significant outcome, context and mechanism variables (cells contain beta coefficients and standard error)*

As can be seen from a comparison of table 7.17 and table 11 in appendix D, perceived behavioural control, implementation, motivation, process, arguments and the interaction term (of motivation, process and arguments) do not significantly predict any of the evaluations.

The results on attitudes allow us to test hypothesis seven. Hypothesis seven was formulated as follows.

7) *Participants in group model building change their attitude toward actions in the problem in the direction of conclusions of the modelling project.*

Since the results indicate that treatment has a significant effect on posttest attitudes, hypothesis seven is not rejected. The regression of posttest attitude on the full set of independent variables reported in appendix D shows that behavioural beliefs are not a significant predictor (beta=-.14, standard error .16). Behavioural beliefs do not significantly predict posttest attitudes. The proposition of the Ajzen (1991) model, that behavioural beliefs act as intervening variables in the relation between information and attitude is therefore rejected on the basis of these data. The other variables influencing attitude in the Ajzen model, subjective norm and perceived control, also have a significant effect. The following hypothesis addresses subjective norm.

8) *Participants in group model building change their subjective norm toward actions in the problem in the direction of conclusions of the modelling project.*

Since the results indicate that treatment has a significant effect on posttest subjective norm, hypothesis eight is not rejected. Neither posttest attitude nor posttest perceived control are significant predictors of posttest subjective norm. Again, according to the Ajzen model, beliefs are an intervening variable in the relation between information and this variable. As can be seen from appendix D and table 7.17 normative beliefs are a significant predictor of posttest subjective norm. To assess the extent to which normative beliefs are an intervening variable in the relation between treatment and subjective norm, normative beliefs were removed from the regression analysis. If normative beliefs are not included in the regression equation, the effect of treatment changes to beta=.73 (standard error .26). We can therefore conclude that there is a direct as well as an indirect (via normative beliefs) effect of treatment on posttest subjective norm. The proposition that normative beliefs are an intervening variable in the relation between information and subjective norm is therefore not rejected on the basis of these data.
Hypothesis nine is the following.

9) *Participants in group model building change their perceived behavioural control toward actions in the problem in the direction of conclusions of the modelling project.*

Since the results indicate that treatment has no significant effect on posttest perceived control, hypothesis nine is rejected. Posttest attitude does have a significant effect, while posttest norm does not have a significant effect on posttest perceived control. The regression of posttest perceived control on the full set of independent variables reported in appendix D shows that control beliefs are not a significantly predictor (beta=-.07, standard error .14). Control beliefs are therefore not an intervening variable in the relation between treatment and perceived behavioural control, contrary to the proposition in the Ajzen (1991) model.

### 7.5.3 Relation of context and mechanism to intentions

The last variable in the Ajzen model which will be analysed on the basis of quantitative data, is intention to perform a behaviour. Similar to the analysis of beliefs, evaluations will first be regressed on pretest scores, correlated error terms and context, mechanism and outcome variables. The result of this analysis is reported in section 6 of appendix D. The following table shows the result of a regression of posttest intention on pretest intention, correlated error terms and context, mechanism and outcome variables.

| *Posttest* | $\beta_0$ | $\beta_1$ *Pretest* | $\beta_3$ *case 1* | $\beta_4$ *case 2* | $\beta_5$ *case 3* | $\beta_6$ *case 4* |
|---|---|---|---|---|---|---|
| intention | .55 (.54) | .29 (.09) | -.07 (.25) | -.30 (.26) | -.26 (.29) | -.14 (.32) |

| *Posttest* | $\beta_7$ *Attitude* | $\beta_8$ *Norm* | $u_{oj}$ | $e_{0ij}$ | *n* |
|---|---|---|---|---|---|
| intention | .47 (.13) | .17 (.10) | .00 (.00) | .27 (.05) | 61 |

*Table 7.9 Multiple regression of posttest intention on correlated error, pretest score, case effects, significant outcome, context and mechanism variables (cells contain beta coefficients and standard error)*

As table 12 in appendix D shows, posttest perceived behavioural control is not a significant predictor of implementation. Similarly, motivation, process, arguments and the interaction term (of motivation, process and arguments) do not significantly predict posttest intention. If these variables are removed from the regression, the effect of the treatment variable becomes insignificant (beta changes from beta=.80, standard error .54 to beta=.28, standard error .40). Removal of treatment from the equation does not significantly change model fit (model fit changes from 93.72 to 94.18, see section 7 of appendix D for a description of model fit). Thus, in a regression of posttest intention on correlated error, pretest intention, treatment, case effects, attitude and norm, treatment is not a significant predictor.
However, according to Ajzen (1991), evaluations are intervening variables between treatment and intention[39]. Therefore it is useful to consider to which extent the relation between treatment and intention changes, when attitude and subjective norm are removed from the equation. In a regression of posttest intention on correlated error, pretest, treatment and case effects, the effect of treatment is significant (beta=1.01, standard error .38). I therefore conclude that there is a significant effect of treatment on posttest intention, but posttest attitude and posttest subjective norm act as intervening variables in this relation. The hypothesis on intention was formulated as follows.

10) *Participants in group model building change their intention toward actions in the problem in the direction of conclusions of the modelling project.*

[39] Only evaluations will be considered as intervening variables between treatment and intention. The Ajzen (1991) model proposes beliefs as additional intervening variables. These will not be considered here as they are not directly related to intentions in the Ajzen model, and because of the weak relations between evaluations and corresponding beliefs (see section 7.4.2).

Since the results indicate that there is a significant (indirect) effect of treatment on posttest intentions, hypothesis ten is not rejected.

### 7.5.4 Relation of context and mechanism to behaviour

Participants' actions in the problem were assessed on the basis of interview data, observations (mainly by the project gatekeeper) and document analysis. A first important topic to consider when assessing behavioural changes, is whether participants are sufficiently able to change their behaviour. As section 7.2.1 indicates, the extent to which participants can implement conclusions of the modelling sessions is quite high. Therefore we can expect that behaviour is at least partly under the respondents' control and (according to the theory of planned behaviour) influenced by changes in intentions and perceived control. The case descriptions in chapter six include an account of actions implemented after the modelling process. Three questions in the interviews are relevant to behavioural change: 1. the extent to which the modelling sessions led to conclusions relevant for a participant's work, 2. the degree to which a participant agreed to the project conclusions and recommendations and 3. expectations about the project's follow-up. In the following answers to these questions are reported for each case, followed by an overall conclusion on hypothesis 11.

For case 1, the answers to the first question indicate that respondents support the project's recommendations, but few draw conclusions for their own work. Although participants in general support the recommendations contained in the project report and indicate that they had gained a number of insights from the sessions, there were no consequences for the way they approached the problem. In general participants seem to wait for a follow-up from the gatekeeper in the form of a more concrete commitment of resources to implementing conclusions. Two participants started implementing conclusions for a specific option which is independent from the gatekeeper's actions. Asked about expectations on the project's follow-up, respondents comment that the model clearly shows the urgency of the problem and points out the necessity of intervening to policy makers (the city council). Since other contextual developments, e.g. subsidies from the national government, help to implement the project's recommendations, the overall expectation is that implementation will be achieved. The overall picture of case 1 is that participants are committed to conclusions but await actions by other stakeholders before starting implementation.

Case 2 and 3 are similar in the sense that participants report insights derived from the model, but draw few conclusions for their own work. However, the reason for this is different. In their view the model is not detailed enough to impact their own work. In case 2 the model revealed a number of problem areas for which participants lacked the information to construct a detailed model structure. The resulting general model was used in subsequent policy formulation meetings for categorising issues and to provide an overview of the complete field. In case 3 a quantitative model was constructed but not fully validated and no final report was drawn up. A participant in this case indicates: 'The model runs were surprising, but the conclusions at this stage are at a global level and present a first eye-opener.' At the time of the interviews the modellers expected to obtain funding to develop the model further, but more urgent problems in the organisation prevented this. In general participants in these cases expect that the model could be helpful in their daily work, provided that it was taken further to cover the problem in sufficient detail. In both cases this effort was not taken, in case 2 because the support offered by the general model was judged adequate and in case 3 because other developments in the organisation drew attention away from the modelling process.

In case 4 the conclusions of the modelling sessions did lead to behavioural changes. Since in this case a large quantitative model was built over a period of several months, the modeller was able to adjust the modelling process to incorporate adequate detail and provide answers to specific questions that came up during this period. In case 4, the housing association management team initially aimed to construct a model for strategic inventory management. In developing the model the managers felt it could provide data to support negotiations with the city council. The modeller prepared the model so that outcomes of model runs could be used to this end. The final model provided support in a number of decisions on inventory management and led to changes in data gathering and accounting systems in both cases. In case 5, the model only indirectly influenced changes in the organisation. The model focussed attention on maintenance and renovation costs and their impact on the company's loans. However, differences in interpretation of financial data prevented the model's use as a strategic planning device. Instead, a financial administration package was purchased that supported strategic and tactical planning.

Overlooking the five cases, it seems clear that the question on the impact of group model building on participant's behaviour is impossible to answer without taking the context of the intervention into consideration. Vennix (1990: 64) already notes that when going from mental models to policy making (actions) and ultimately policy effects, it becomes progressively more difficult to determine the impact of factors outside of the intervention. It seems therefore that a contingent answer to hypothesis 8 is in place.

First, a distinction needs to be made between two categories of behavioural change: behavioural change with regard to the options identified in the questionnaires, and effects on additional options that were not mentioned in the questionnaires. The latter category represents unexpected or side effects. Second, there is the degree to which behavioural change is supported either by the modeller, gatekeeper or outside developments in the problem. A last comment is that new insights into the problem might not lead to behavioural changes, but instead support decisions that were already made.

Options specified in the questionnaire differ from additional options with regard to the level of generality at which they are formulated. Since in the questionnaires respondents are asked to identify options relevant to their own work, these tend to be on a specific level and address a particular part of the problem that is being modelled. If information exchanged during the modelling sessions is to be relevant to issues on this level of detail, either the model needs to be on a specific level (case 4 and indirectly, case 5) or conclusions are to be worked out into an implementation plan (case 1). If conclusions remain on a general level general insights are gained and general guidelines for policies might be derived (case 2 and 3), but lower level decisions in daily work are not influenced. In the latter case the specific options mentioned in the questionnaire are not likely to be influenced, although there might be unexpected effects on other options.

This connects to the second important influence on behavioural change: the level of support. Support for implementing recommendations from the modelling sessions comes from three sources: the gatekeeper, modeller or contextual developments. In case 1 the gatekeeper's implementation plan serves as a condition without which a number of participants will not implement conclusions. In case 4 and 5 the modeller is able to adjust the modelling process to accommodate new client questions. A participant in case 1 noted that as a result of the model he intended to spend more time in the problem area but this was prevented by the large number of colleagues on sick leave. An example of a contextual development that works to support the intended actions are the government subsidies that are expected to finance some of the recommendations in case 1. These examples in effect constitute changes in perceived behavioural control. It seems that the level of support is an important influence on behavioural change, and only partially in control of the modeller or gatekeeper.

In addition to the level of concreteness of project recommendations and actions, and the degree of support for changes in behaviour, a third issue is relevant in assessing the impact of modelling on actions. Several authors in the field of organisational change (Argyris, 1992) and more specific for modelling interventions (Verburgh, 1994: 225) note that new insights do not necessarily translate to changes in behaviour. Alternatively, new insights might also point to unexpected benefits of actions that were already undertaken or planned. In this way new information increases the confidence in decisions already made, and does not lead to choice for a different action alternative. This issue points again to the fact that modelling goals are related (see e.g. section 2.5.6) and the difficulty of considering outcomes in isolation.

Hypothesis 11 was formulated as follows.

11) *Participants in group model building change their behaviour in the problem in the direction of conclusions of the modelling project.*

The conclusion with regard to hypothesis 11 is therefore that group model building leads to changes in participants' actions, under the conditions that 1. the model generates information with regard to the actions concerned (actions and model content are on the same level of generality), and 2. support by the modeller, gatekeeper and contextual developments is sufficient. Hypothesis 11 is not rejected.

This concludes the treatment of relations between context, mechanism and outcome. In the following context-mechanism-outcome configurations are addressed.

## 7.6 Context - mechanism - outcome configurations

Section 7.3.1 described the score of group model building on mechanism variables (ability to process information and arguments). Outcome variables (cognitions, evaluations, intentions and behaviour) were described in section 7.4.1. This section addresses the context - mechanism – outcome configurations that were found in the analysis of the group model building literature in chapter three. In chapter three a number of differences were found between qualitative models, small quantitative models and large quantitative models. The cases in this study can be grouped in these categories as in the following table.

| *Configuration* | *Case* |
|---|---|
| qualitative model | case 1 (safety in a city district)<br>case 2 (Directorate General) |
| small quantitative model | case 3 (telecommunications provider)[40] |
| large quantitative model | case 4 (housing association East)<br>case 5 (housing association West) |

*Table 7.10 Mechanism – outcome configurations and cases included in this research*

Below the differences between the context, mechanism and outcome of these modelling projects are discussed.

*Context*

On the basis of the literature analysis in chapter three, qualitative modelling is expected to be used in more complex problems than quantitative approaches. However, as table 6.2 illustrates, problem complexity does not differ between cases. The meta analysis also indicated that problem importance did not differ between configurations. Appendix D showed no differences between motivation to process information (importance of the problem to the organisation). Differences in outcomes can therefore not be attributed to either problem complexity or problem importance. Finally, the meta analysis indicated no differences between organisational variables (sort, sector or size of client organisation). Indeed, the only organisational characteristic that consistently relates configurations is sort (profit, non-profit or governmental). Both qualitative modelling projects are initiated by government institutions, although case 1 involves profit and non profit organisations as well. Because the literature analysis did not uncover any effects of organisation sort on modelling process or outcomes, it seems that the five cases do not show important differences. The relation between problem complexity and modelling format is not found in the five cases researched in this study. This result is relevant to hypothesis 12, which was formulated as follows.

[40] In the meta analysis reported in chapter 2, models containing less than 50 variables were rated as 'small'. In case 3 the model has a total of 99 variables. I will treat this case as representative of a small model since it differs substantially from the size of the models built in case 4 and 5, and since the meta analysis includes only very few models that are between 50 and 99 variables.

12) *With regard to the context of group model building,*
   a. *qualitative models are more likely to be used in messy problems than quantitative models;*
   b. *model types do not differ with regard to organisational characteristics;*
   c. *model types do not differ with regard to problem importance;*

Since no differences were found between context variables between configurations, part a of hypothesis 12 is rejected. Parts b and c are not rejected.

*Mechanism*

With regard to the mechanism of group model building, the literature review in chapter three revealed that large quantitative models take longer to construct and involve more participants than any other model type. No differences were found between process and argument quality (communication). Duration and number of participants are addressed first. The duration of modelling projects and the number of participants involved are depicted in table 6.1. The first large quantitative modelling project was completed in eight months, while the second took 20 months to complete. The three other modelling projects had a duration of six, 11 and two months respectively. This difference is insignificant (t=-1.172, one-sided significance .20). The two large quantitative models are constructed with four and six (averaging over the three project phases) participants, while the other three models are constructed with 17, ten and again ten participants. Clearly the number of people involved in the large quantitative modelling projects is smaller than in other projects, contrary to expectations.

The following table shows mean scores and standard deviations of process and argument quality for the five cases in this study.

| | *case 1* | *case 2* | *case 3* | *case 4* | *case 5* |
|---|---|---|---|---|---|
| process quality | 3.77 (.25) n=11 | 3.67 (.41) n=6 | 4.38 (.42) n=8 | 3.71 (.63) n=4 | 3.53 (.55) n=5 |
| argument quality | 3.48 (.32) n=11 | 2.87 (.64) n=6 | 3.09 (.39) n=8 | 3.22 (.48) n=3 | 3.39 (.73) n=5 |

*Table 7.11 Mean scores, standard deviations and n of process and argument quality per case*

As can be seen from the table, there are no large differences with regard to process or argument quality between cases. The only score below neutral, is the score of case 2 on argument quality. There are no significant differences between scores at the .01 level. The expectation that communication does not differ between model formats therefore is not rejected on the basis of the data in this study. The hypothesis on mechanism was the following.

*13) With regard to the mechanism of group model building,*
  *a. large quantitative models take longer to construct than other types of models;*
  *b. large quantitative models involve a larger number of participants than other types of models;*
  *c. model types do not differ with regard to ability to process information;*
  *d. model types do not differ with regard to argument quality;*

Similar to context variables, no differences were found between scores of mechanism variables between configurations. Parts a and b of hypothesis 13 are rejected, parts c and d are not rejected.

*Outcome*
With regard to outcome, the analysis focuses on the variables in the Ajzen (1991) model. The differences between cases with regard to beliefs are shown in table 7.16. With regard to behavioural beliefs, only cases 1 and 2 score significantly different from the other case: case 1 higher and case 2 lower than case 5. Again this difference cuts across boundaries of configurations as both case 1 and 2 are qualitative projects. With regard to normative and control beliefs there are no significant differences between cases.
Table 7.17 shows case effects with regard to evaluations. All differences in evaluations again cut across configurations. With regard to attitudes, case 3 scores significantly higher than other cases. Case 4 scores significantly lower than other cases with regard to subjective norm. With regard to perceived control, case 1, 2 and 3 score lower than cases 4 and 5.
With regard to intentions, table 7.18 shows that there are no significant case effects.
As described in section 7.5.4, the impact of modelling on participants' actions depends on 1. the extent which the model and actions are specified at the same level of generality and 2. implementation is supported by either the gatekeeper, modeller or contextual developments. In the cases in this study, both of these conditions did not depend on configurations. Of the three quantitative models, one case did not provide detailed recommendations and did not support implementation (case 3) while two models did (case 4 and 5). The expectation that behavioural change does not depend on configuration therefore seems to be confirmed by the data.

The last hypothesis was formulated as follows.

*14) With regard to the outcome of group model building,*

*a. participants in quantitative modelling projects and participants in qualitative modelling projects do not differ with regard to changes in behavioural beliefs;*

*b. participants in quantitative modelling projects and participants in qualitative modelling projects do not differ with regard to changes in attitudes;*

*c. participants in quantitative modelling projects change their normative beliefs more than participants in qualitative modelling projects;*

*d. participants in quantitative modelling projects change their subjective norms more than participants in qualitative modelling projects;*

*e. participants in quantitative modelling projects and participants in qualitative modelling projects do not differ with regard to changes in control beliefs;*

*f. participants in quantitative modelling projects and participants in qualitative modelling projects do not differ with regard to changes in perceived behavioural control;*

*g. participants in quantitative modelling projects change their intentions more than participants in qualitative modelling projects;*

*h. participants in quantitative modelling projects and participants in qualitative modelling projects do not differ with regard to changes in behaviour.*

Since no significant differences between outcomes of group model building were found, parts c, d and g are rejected. Parts a, b, e, f, and h are not rejected.

In conclusion, the data do not show significant differences between mechanism – outcome configurations. Although a number of differences between cases can be found, differences within configurations are frequently larger than differences between configurations. The data therefore seem to support the expectation that organisational characteristics, problem importance, process quality, argument quality, changes in beliefs, evaluations and behaviour do not differ between model formats. The expected difference with regard to duration, number of participants, problem messiness, normative beliefs, subjective norm and intention is not confirmed. However, results need to be interpreted with caution since there are only five cases included in the analysis. This concludes the description of mechanism – outcome relations and thereby the last section of analysis of results.

## 7.7 Summary

In this chapter the results of the analysis of five cases were presented with regard to context, mechanism and outcome. Before summarising the results, it is useful to consider again the threats to the validity of conclusions discussed in section 5.3.2.

The first threat, history, was tested by asking a number of participants about their perception of the reason for changes in evaluation. Since the insight of respondents in changes and reasons for changes was found to be limited, the effect of history cannot be ruled out completely. The second threat, regression to the mean, was tested by regressing outcomes with regard to beliefs, evaluations and intentions on pretest scores. Since this did not lead to different conclusions, regression to the mean seems to have a limited effect in this study. The threats of maturation and testing were checked by contrasting multiple sources of data. Quantitative and qualitative data were compared and in general pointed to similar conclusions, which increases the confidence in the validity of results. The impact of the last threat on validity, instrumentation, was reduced by using similar measurements in pretest and posttest with regard to beliefs, evaluations and intentions. In conclusion the main impact on the validity of this study's results is history. In the choice of the research design in section 5.3.1, the benefits and drawbacks of studying a realistic environment were outlined. The choice for studying real world applications of group model building was made because the realism introduced by this setting outweighed the drawbacks of reduced control. The consequence is that (problem and organisational) variables outside of the intervention can be assumed to have an effect on participants' ideas, while it is difficult to estimate their relative strength.

The main results of the study are the following. Contextual variables that were expected to influence the impact of group model building were motivation to process information, extent to which participants could implement conclusions, their age and years working with the organisation. Problem complexity and motivation to process information are high for all participants. Contextual variables turn out not to have specifying effects on either mechanism or outcome variables.

With regard to mechanism, argument quality and process quality are high in all cases.

The expected relations between outcomes refer to the relation between intentions and attitudes, norms and control and between evaluations and beliefs. With regard to the first set, expectations are largely confirmed. If confronted with the Ajzen (1991) model, participants fail to find important variables that need to be included in the model. However, the relation between evaluations and beliefs does not confirm to expectations. Only for subjective norm do evaluations and beliefs show significant correlations. The following table shows the overall results with regard to hypotheses.

| | |
|---|---|
| **Context**<br>Group model building leads to … | |
| *Motivation* | |
| 1. High motivation to process information: | not rejected |
| **Mechanism**<br>Group model building leads to … | |
| *Process* | |
| 2. High quality decision process | |
| a. high ability to process information: | not rejected |
| b. positive comparison to traditional meetings: | not rejected |
| *Arguments* | |
| 3. Exchange of argument for evaluation change: | not rejected |
| **Outcomes**<br>Group model building leads to … | |
| *Beliefs* | |
| 4. Change in behavioural beliefs: | rejected |
| 5. Change in normative beliefs: | rejected |
| 6. Change in control beliefs: | not rejected |
| *Evaluations* | |
| 7. Change in attitude towards behaviour: | not rejected, direct effect |
| 8. Change in subjective norm: | not rejected, direct effect and indirect effect through normative beliefs |
| 9. Change in perceived behavioural control: | rejected |
| *Intention and behaviour* | |
| 10. Change in intention: | not rejected, indirect effect through changes in attitude and subjective norm |
| 11. Change in behaviour: | not rejected, under the conditions that 1. the model and behavioural options were at the same level of generality and 2. support for implementation was adequate |
| **Context – mechanism – outcome configurations** | |
| 12. Context | configurations have no differential impact |
| 13. Mechanism | configurations have no differential impact |
| 14. Outcomes | configurations have no differential impact |

*Table 7.12 Results with regard to the hypotheses*

On the basis of the literature analysis in chapter three, a number of similarities and differences between model formats were expected. Specifically, all formats were expected to score equally on communication (process and argument quality), insight (evaluations and beliefs) and behavioural change. Qualitative models were expected to have less influence than (small and large) quantitative models on commitment (intention) and consensus (subjective norm and normative beliefs). On the basis of the data no significant differences between model formats could be found. Since there are only five cases included in this study, this result has to be interpreted with caution. Results are depicted in the figure below.

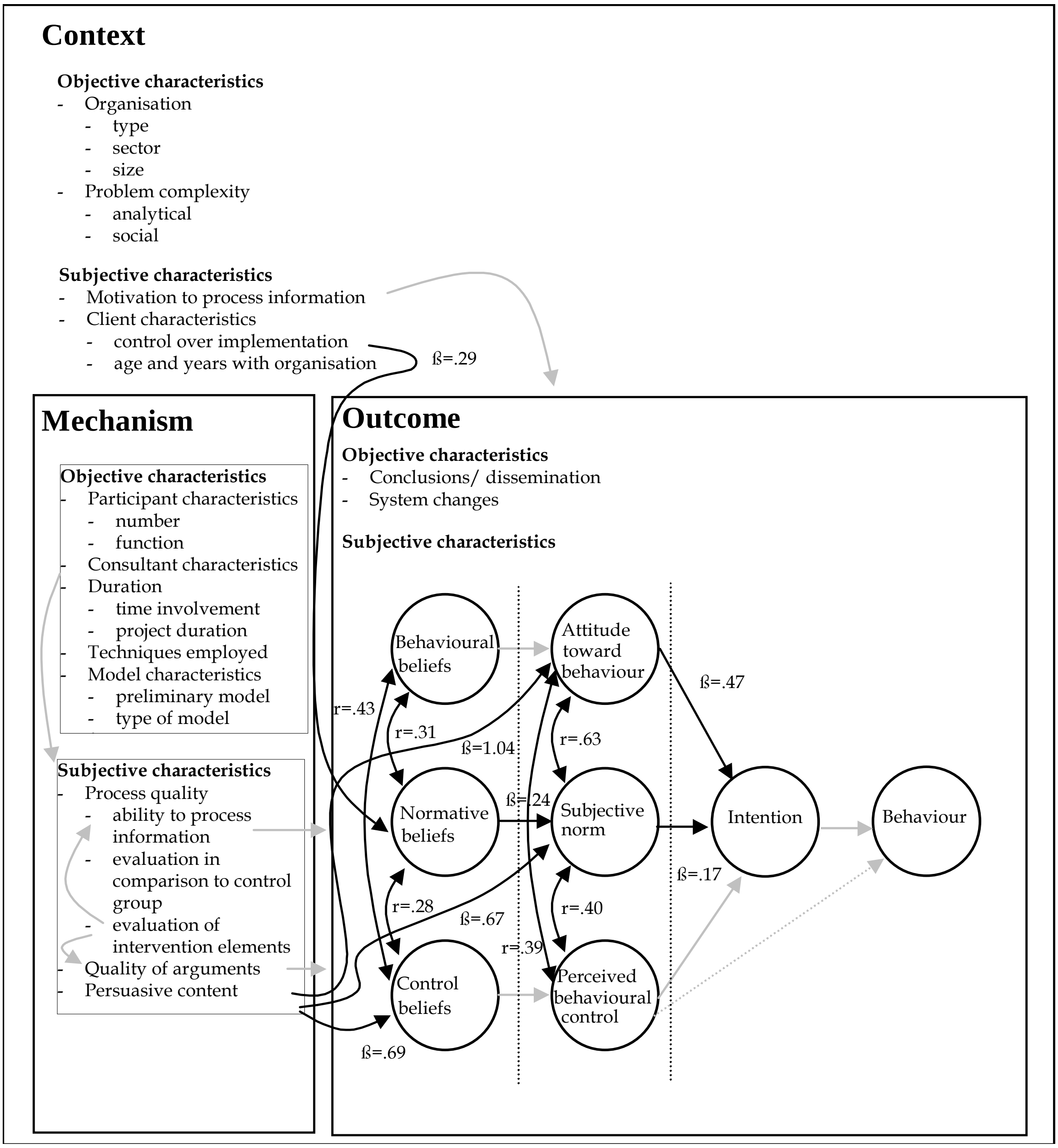


*Figure 7.5 Relations between context, mechanism and outcome elements, the dotted lines indicate that intentions are regressed separately on context and mechanism variables and evaluations, independent from the regression of evaluations on context and mechanism variables and beliefs*

In interpreting the figure, please keep the following in mind. In order to present an overview, relations which were rejected are still included in the figure but depicted in grey. The relations of intention and perceived control to behaviour are not quantitatively measured and therefore also depicted in grey. Other relations between subjective outcome variables (the Ajzen framework) are indicated for posttest measurements, as described in section 7.4.2. The beta coefficients for the relations of context and mechanism variables to beliefs, evaluations and intention are calculated as described in section 7.1.2. Please recall that the regression of intentions on context variables, mechanism variables and evaluations is performed separately from the regression of evaluations on context variables, mechanism variables and beliefs.

This concludes the chapter on analysis of results. The following chapter provides a discussion of assumptions and conclusions of this study.

# Chapter 8 Conclusions and discussion

## 8.1 Introduction

This chapter presents conclusions and a discussion of this study on group model building. The central assumption of the present study is that it is useful to look at group model building through the lens of persuasion and attitude - behaviour theory. It was assumed that the central elements of the context, mechanism and outcome of modelling projects could be related through these theories. Chapter two provided the background of this study by addressing theories on decision making and group model building as a method to intervene in messy problems.

The benefits of an overall framework that connects elements of the intervention to expected outcomes, followed from a survey of the literature on group model building, reported in chapter three. Important outcomes of group model building such as refinement of mental models and implementation of system changes are mostly considered in isolation and are not related to the process of modelling. From the literature it appears that somehow the communication during the modelling process impacts mental models, and through changes in mental models might influence implementation. However, these relations are not explicitly discussed in the literature on system dynamics. In addition, empirical studies employ different definitions and measurement approaches for several outcomes. The lack of clearly defined concepts and relationships leads to inconsistent findings in group model building research. Several studies find that participation in modelling leads to consensus on the problem, while other studies fail to find such an effect. Without clear and consistent definitions of key variables, it is impossible to determine whether these findings reflect real differences between modelling projects or merely differences in the definition of outcomes.

A conceptual model helps to identify the relevant differences between applications of group model building and contributes to understanding why a result is found in some studies, but not in others. Chapter four described a conceptual framework on the relation between persuasive communication, belief and evaluation change and behaviour. In the previous chapter the results with regard to this framework were assessed.

The preceding chapters point to several conclusions on the merits of the framework and possible ways to continue refining both the conceptual model as well as the measurement approach. This chapter first addresses the conclusions with regard to the hypotheses and the conceptual model, focussing on the elements of persuasion and attitude – behaviour theory. The second set of conclusions is related to the measurement method which is the topic of section 8.3. On the basis of the results with regard to conceptual and measurement issues, we are able to formulate recommendations with regard to future group model building interventions. These are addressed in section 8.4. Section 8.5 identifies directions for future research.

## 8.2 Conceptual model

In this section the conclusions with regard to the hypotheses and the conceptual model on the impact of group model building on evaluations and behaviour are presented. For the conceptual model, elements of persuasion theories (Chaiken et al., 1989; Petty and Cacioppo, 1986) and a model of the impact of attitudes on behaviour (Ajzen, 1991) were combined. The research on group model building (see chapters two and three) offered two main reasons for using the proposed framework. First, the central concepts in research on group model building have a clear equivalent in the conceptual model. This makes it possible to use definitions from existing theories for those concepts that were not clearly or consistently defined in the system dynamics literature. Second, the benefit of the conceptual model over existing conceptualisations is that it a. relates intervention elements to expected outcomes, and b. specifies relations between outcomes. In this sense the conceptual model seems to offer a useful integration of relevant variables. A comparison on theoretical grounds of existing group model building research to the proposed conceptual model is reported in chapter three and four. In the remainder of this section I focus on the empirical data, and address the hypotheses in turn.

### 8.2.1 Results with regard to persuasion theories

In this study two theories on persuasion were used: the Elaboration Likelihood Model (Petty and Cacioppo, 1986) and the Heuristic Systematic Model (Chaiken et al., 1989). This section discusses the empirical results reported in the last chapter, and compares these to the empirical and theoretical literature on group model building. Gaming research, which is considered in the following section, is not discussed here as it does not report on relevant empirical results (i.e. the relation between communication and evaluation change). The results of the related hypotheses are as follows.

- *Hypothesis 1 on motivation to process information: not rejected*
- *Hypothesis 2 on process quality*
  *a. ability to process information: not rejected*
  *b. comparison to traditional meetings: not rejected*
- *Hypothesis 3 on arguments: not rejected*

Both the ELM and the HSM posit that attitude change is a function of three variables: motivation to process information, ability to process information, and persuasive arguments. Both motivation to process information (chapter six and section 7.2) and ability to process information (section 7.3) were found to be high. Also, modelling was shown to generate persuasive arguments (section 7.3). We can conclude that in group model building all three determinants for evaluation change are present. However, section 7.5 showed that neither ability nor arguments predict change in beliefs or evaluations. The regression of beliefs and evaluations on context and mechanism variables, motivation, ability to process information, arguments, and the interaction of motivation, ability and arguments are not significant.

In conclusion, we are faced with a situation in which both the conditions for change and change itself are present, but both measures are not related. Taken to their extreme, we can interpret these results as indications that the Elaboration Likelihood Model (ELM) and the Heuristic Systematic Model (HSM) do not offer a useful description of belief and evaluation change in this domain. However, since both models serve to integrate numerous research outcomes in various domains (Eagly and Chaiken, 1993) this seems a premature conclusion. Instead three alternative explanations for these results come to mind: a. the measurements of either the conditions for change, or belief and evaluation change, or both, do not validly represent the theoretical constructs; b. although conditions for change were present they did not pertain to the specific beliefs and evaluations measured in this study; c. the changes in evaluations are due to the peripheral route instead of the central route.

*Validity of measurements*

The first possibility is tested in two ways. First, the analyses in sections 5.5.2 to 5.5.4 indicate that the reliability of the scales for the Ajzen and persuasion variables are satisfactory. Second, the interviews give an indication of participants' own interpretation of the process and outcome of the intervention. These interpretations show a clear resemblance to the definition of the central constructs. This explanation therefore seems unlikely. The correspondence of questionnaire and interview data is addressed again in section 8.3 on the measurement method.

*Compatibility of measurements*

The second possibility seems more promising. In general, studies based on ELM and HSM make use of highly restricted communication contexts. Researchers frequently employ arguments that are tested for their effects on specific attitudes, enabling studies to focus on detailed manipulations of (combinations of) motivation, ability or argument quality (Eagly and Chaiken, 1993). In this study on group model building, general measures of ability and argument quality were related to more specific measures of beliefs and evaluations. A respondent is asked to rate her general perception of the degree to which the modelling sessions enabled her to process arguments and her general perception of the quality of exchanged arguments. In addition, evaluations and beliefs on specific actions are assessed before and after the intervention. Since the content of the discussion in the modelling sessions is explicitly not controlled by the facilitator, there is no direct relation between arguments exchanged and the evaluations or beliefs measured by the questionnaires. The information exchanged in the sessions is essentially produced and interpreted by the participants. Several measures were taken to ensure a correspondence between content of the modelling sessions and evaluations or beliefs included in the questionnaires. First, participants were asked to focus on actions relevant to the problem at hand, which can be expected to surface as important discussion topics in the modelling sessions. Second, these self-generated actions were related to the model and project report, which summarise the discussion in the sessions, by several coders. Only a small subset of actions could not be related to the content of either the model or the report. Third, participants were asked whether changes in evaluations from pretest to posttest were a result of the sessions or information gained or developments outside of the sessions. However, this question was posed to only a minority of the respondents and participants in general seem to have limited insight in what they learned during the sessions (see section 7.3). The inaccurateness of people's insight into their own cognitive processes is noted in the psychological literature as well (Nisbett and Wilson, 1977). Information gained outside of the sessions can be expected to have a substantial influence on participants' opinions, but this is an integral part of testing group model building as a realistic intervention in real world problems. Group model building is expected to incorporate developments in the organisational context, reflect and combine relevant information, and therefore have an influence on participants' ideas over and above developments in the real world problem. In sum, these three measures seem adequate to at least indirectly promote a correspondence between session content and evaluation or belief change. However, the creative combination of information in the modelling sessions might very well lead the discussion to take an unexpected turn, and therefore go beyond the actions identified in the pretest questionnaires.

A more basic problem is that even in hindsight it is very difficult to estimate how information in the sessions impacted a participant's set of beliefs and evaluations. Scheper (1991) describes how interpretation of information is essentially an idiosyncratic process, leading each participant in the modelling discussions to interpret information in their particular way. In the description of HSM and ELM their consideration of individual knowledge was mentioned. The models assume that arguments are contrasted with existing knowledge to estimate their validity and valence. A particular argument therefore has a different impact on different receivers, depending on their prior knowledge. One might therefore conclude that only the respondent is able to indicate the impact of bits of information identified in the modelling sessions. Verburgh (1994) seems to go a long way in this direction as he argues for an insider perspective in assessing impacts of modelling interventions. However, as section 7.3 indicated, an insider view in itself is of limited value, since respondents do not have a clear idea on which insights they gained from the modelling sessions. A confrontation of assessments by an outside observer with participants' self-reflections, as is advocated in the case study literature (e.g. Yin, 1984) therefore seems promising. Nevertheless it seems that authors in the field of decision support have divergent opinions on the degree to which a decision maker's personal interpretation is accessible to outsiders. More so than to their empirical tools, this seems to relate to the philosophical orientations of authors. Authors such as Scheper (1991) and Verburgh (1994) seem to adhere to an individualistic paradigm, emphasising subjective meaning, while Eden (1992c) and Vennix (1990; 1996) are inclined to take a constructivist view, which puts more emphasis on intersubjective factors. Since this study is in no way intended as the last answer in a philosophical debate, I do not address this issue further but conclude with Weick's (1995) assertion that some people have more room to construct their own world than others. In other words, organisational factors do place boundaries on individual's mental models and behaviours.

*Peripheral influences*

In this study, the central route of persuasion was focused on. The informational content and arguments exchanged in the modelling sessions were identified. However, Eden (1992d) points out that the peripheral channel may have an additional influence on change in evaluations. The remark of a participant in case 1 makes this explicit. This respondent remarks that she has changed her opinion not so much on the basis of the content of the discussion, but because of its general negative *tone*. However, since no extensive data on peripheral variables were gathered, it is impossible to determine to what extent the peripheral route was operational in the cases included in the present research. This third explanation for the absence of a relation between conditions for evaluation change and evaluation can therefore not be ruled out.

In conclusion, in group model building the conditions for evaluation and belief change are present, but the impact of modelling on specific beliefs and evaluations is difficult to predict. In this sense a more specific context – mechanism – outcome configuration is identified: the general idea that modelling influences opinions seems

to be confirmed, and there seems to be room for studies that are more restricted in scope, where change in a particular evaluation and related beliefs is researched in more depth. With regard to the original formulation of the conceptual model in this study, the following can be concluded. In section 4.4 the conceptualisation of communication in persuasion theories was compared to the group model building literature. Prominent contributions to the system dynamics literature on communication are Andersen et al.'s (1994) design and operater logic, and Lane's (1992) concept of negotiation as a process of aligning goals and resources. The notion of a hierarchy in goals was introduced as a central principle that underlies both types of logic (negotiation as well as persuasion as described by the ELM and HSM). The idea of a hierarchy in goals was used in the remainder of this study, in particular with regard to assessment of beliefs, evaluations and behaviours. In hindsight, assessing communication (motivation, ability and arguments) on a general level is not in line with the idea of a hierarchical ordering of goals. Again this points to a more specific context – mechanism – outcome configuration and the benefit of more specific studies.
The second conclusion with regard to the conceptualisation of communication is that the assumption that only the content of communication (arguments) influences changes in participants' opinions, might be too restricted. As one participant in the first case remarked, the tone of the discussion, i.e. the general impression of positive or negative character, is most probably an influence as well.

On the basis of the present study two additional pitfalls in conceptualising communication can be identified:

- In the present study arguments were scored as negative or positive. A positive argument was expected to lead to a more positive attitude, while a negative argument was expected to lead to more negative attitudes. However, if the polarity of arguments is conceptualised as a continuous scale this becomes more complicated. An argument that is rated in the present study as 'positive' might, on a scale from very negative (1) to very positive (5) turn out to have a score of 4. With attitudes scored on a similar scale, which effect will this argument have on an attitude that scores 4.5 in the pretest?
- A further complication arises when the importance of the problem is seen not as a constant value, but as changing over the modelling process. That this is relevant can be concluded from a case on cooperation between business units (Akkermans, 1995 case software services a). At least one participant in this case felt the problem, as formulated at the outset of the sessions, was not important to his business unit. During the sessions however, it was shown that the problem related directly to the survival of the complete organisation, including his own unit. We can therefore assume that importance and

therefore motivation to process information changes dynamically, as a function of the information discussed in the sessions. According to the HSM and ELM this means that a participant pays attention to heuristics at the outset of the modelling project (since perceived problem importance and therefore motivation is low) and only gradually changes to central processing and comes to appreciate arguments exchanged.

In conclusion, the proposed conceptual model can be further refined but the complex context of group model building interventions poses several problems for the use of persuasion and attitude – behaviour theories. The following section addresses the theory of planned behaviour .

### 8.2.2 Results with regard to the theory of planned behaviour

On the basis of the theory of planned behaviour, the expectation was formulated that during modelling, persuasive messages would be exchanged, leading to change in beliefs and corresponding evaluations (attitudes, subjective norms and perceived control). Evaluation change in turn leads to change in intentions and behaviours. Hypotheses 4 to 9 in this study relate to beliefs and evaluations. Results with regard to these hypotheses were as follows.

- *Hypothesis 4 on behavioural beliefs: rejected*
- *Hypothesis 5 on normative beliefs: rejected*
- *Hypothesis 6 on control beliefs: not rejected*
- *Hypothesis 7 on attitude: not rejected*
- *Hypothesis 8 on subjective norm: not rejected*
- *Hypothesis 9 on perceived control: rejected*

Two results with regard to evaluations and beliefs are especially noteworthy. First, perceived behavioural control is the only evaluation that remains unchanged over the course of a modelling project. Although group model building focuses on finding policy levers that can alleviate problematic behaviour and uses simulation to find implementable options, participants do not feel they have greater control over actions. Second, the results on evaluations and beliefs are contrary: for each evaluation that is found to change, the corresponding belief remains unchanged and vice versa. Both issues are addressed below.

*Change in evaluations*

The results of this study described in the previous chapter show that attitude and subjective norm change after participation in group model building, while perceived control does not change. One way of taking a closer look at this outcome is by comparing it to other results that are found in the literature. No application of the theory of reasoned action to the measurement of an intervention could be found in the social psychological literature[41]. The results of the present study are therefore compared to relevant studies on system dynamics and gaming. In the following table the results are reported for evaluation studies on group model building that included corresponding variables, and three studies on gaming.

| *Study* | *Concept* | *Result* |
|---|---|---|
| **Group model building** | | |
| Verburgh (1994) | number of exogenous concepts (control) | no change |
| Huz (1999: 70) | presence and importance of goals (attitude)<br>presence and importance of means (control) | no change<br>increase |
| Knops (2000) | attitude<br>subjective norm<br>control | increase<br>increase<br>increase |
| Present study | attitude<br>subjective norm<br>control | increase<br>increase<br>no change |
| **Gaming** | | |
| Vennix (1990: 212) | number of goal variables (attitude)<br>number of instrument variables (control) | increase<br>increase |
| Rouwette et al. (1998) | attitude<br>subjective norm<br>control | increase<br>no change<br>no change |
| Rouwette et al. (2003) | attitude<br>subjective norm<br>control | increase<br>no change<br>increase |

*Table 8.1 Changes in attitude, subjective norm and control reported in modelling and gaming research*

In the table above, three studies do not include direct measurements of the concepts in the Ajzen model, but do report on concepts that can be related to attitude or perceived behavioural control. The study by Verburgh (1994) reports one variable that can be related to perception of control: the number of exogenous concepts in

[41] One study uses the theory of reasoned action to address the impact of an intervention (Ajzen and Fishbein, 1980). Since this study does not include perceived control, it will not be used for comparison to the results of this study.

participants' mental models. It can be assumed that an increase in the number of exogenous concepts lowers the degree to which model behaviour can be steered, and therefore lowers perceived control. Huz (1999) measures presence and importance of five types of goals, and finds no change between pretest and posttest. This can be taken to indicate that participants' attitudes did not change as a result of the modelling sessions. In addition Huz reports on presence and importance of three types of means (control). Presence of one type of means is found to increase. Vennix (1990) finds a significant increase in both the number of goal variables as well as the number of instrument variables.
From the results in table 8.1 it appears that five out of six studies (including the present one) report a positive effect on attitudes. The effect on subjective norm is reported in four studies, of which the two modelling studies find an increase while the two gaming studies do not find significant changes. Interestingly, one of the two gaming studies (Rouwette et al., 2003) explicitly includes the expectation that norms will not change, as important referents are not present during the intervention. This is an important difference with the other three studies where important referents participate in the game or modelling process. The results with regard to subjective norm are therefore inconclusive. With regard to perceived control, three out of seven studies report an increase. The three positive results are however not completely comparable to the present study.[42] The limited number of studies that are comparable to the present research thus point in the same direction: group model building does not have a significant effect on perceived control.

In summary, a small number of studies supports the findings in this study with regard to the positive effect of group model building on attitudes, and the absence of an effect on perceived control. This similarity in results increases the confidence in the relation between group model building and evaluations found in the present study. The low number of subjects involved in the separate studies however limits their power, which lowers the possibility of detecting small changes in variables. Results should therefore be tested in further studies. The outcomes with regard to beliefs are discussed in the following section.

*Correspondence of change in evaluations and beliefs*

The Ajzen (1991) model postulates that the causal influence on behaviour runs from beliefs to attitude, subjective norm and perceived control. In other words, the theory

[42] Huz (1999) reports an increase in only one of three scales measuring presence of means. In the study by Knops (2000) participants are students, whose behaviour (voting for or against a proposed action) is rather easy to implement. Rouwette et al. (2003) report an increase in control over entrepreneurial behaviour. However, a large element of this behaviour is operating a new computerised planning system which is trained in a week long gaming simulation.

proposes that causation flows in a single direction (Eagly and Chaiken, 1993: 185). Ajzen (1991) maintains that an attitude is formed on the basis of an aggregation of beliefs (a similar argument would hold for subjective norm and perceived control). This would lead us to expect that group model building would have a comparable impact on beliefs and the associated evaluation: if modelling results in change in outcome beliefs, attitudes would have to change as well.[43] However, the data show that correlations between beliefs and evaluations are not strong. There is therefore no reason to expect that change in beliefs would necessarily correspond to change in evaluations.

With regard to the correspondence of beliefs and evaluations, the difficulty of distinguishing attitudinal from normative elements is especially striking. Section 7.4.2 shows that there are strong correlations between personal and normative terms in the Ajzen model, both with regard to evaluations (attitudes and subjective norm) as well as beliefs (behavioural beliefs and normative beliefs). Attitudes and norms are significantly correlated in pretest and posttest. Normative beliefs are a significant predictor of subjective norms in both pretest and posttest, but only in the posttest do behavioural beliefs predict attitude. In pretest and posttest normative beliefs correlate to attitudes, and behavioural beliefs have a strong correlation with subjective norm. It seems therefore that behavioural and normative beliefs are difficult to separate in this study. The difficulty of distinguishing between both types of beliefs is recognised in the literature on the attitude-behaviour relation. Miniard and Cohen (1981) argue that the perceived impact of one's actions on other people can generally equally well be stated in terms of a behavioural belief or a normative belief[44]. In this study, alternative formulations are for instance the following: increasing attention to career planning will lead to retaining more employees (behavioural belief) or employees think I should pay more attention to career planning (normative belief). Eagly and Chaiken (1993: 171) list other problems with the distinction of behavioural and normative terms. Ajzen (2001) surveys a number of studies that find different relative contributions of attitudes and subjective norms to the prediction of intentions. For instance, priming personal versus collective concepts leads to a change in the relative weight of each concept. However, he points out that these differential impacts underline the conceptual distinction between attitudes and subjective norms. In the light of these contributions, the fact that in this

[43] In this section two issues are discussed: a. correlation between beliefs and evaluations at one point in time and b. correspondence between change in beliefs and change in evaluations. It is maintained that if a would be true, b would necessarily follow.

[44] Recall that in assessing the expected direction of change (section 5.4.2) exchanged arguments were expected to change attitude and subjective norm in a similar direction, since new information constituted both a desire on the part of an important referent as well as a new outcome of behaviour.

study behavioural beliefs have a stronger relation to subjective norms than to attitudes is not a complete surprise. The domain of the present study provides additional reasons to expect a relation between normative and personal elements. Since in the domain of this study (complex organisational problems), actions are particularly likely to be influenced by ideas on stakeholders' needs and goals (i.e. normative beliefs) the likelihood that personal and normative ideas are closely intertwined is even greater than in the less complicated behaviours to which the theory of planned behaviour is usually applied.

The relation between personal and normative elements is however only a specific instance of the more general issue, that the relation between beliefs and evaluations is more complicated than the Ajzen (1991) model proposes. The relative independence of beliefs and evaluations is recognised in the decision making literature (Eden, 1992d: 208):

> *'In group decision making we expect to see a shift in emotional attitudes as well as a cognitive shift to the problem situation. Changes in emotional attitude reflect, in part, the role of intuition and hunch which leads to a feeling of comfort about the path ahead […]. Cognitive shifts are about someone "changing their mind" – changed beliefs, changed values, and changes in the salience of particular values […] As I have argued above, it is more likely that the procedural reality will influence emotional attitudes, and substantial rationality will influence shifts in cognition; however, each supports the other.'*

In addition to the close relation between cognition and evaluation, Eden also refers to different paths through which beliefs and evaluations might be influenced. Procedural rationality is concerned with following the proper process, while substantive rationality refers to the arguments that can be brought to bear on a person's position. This goes back to the discussion on persuasion.

In conclusion, two issues with regard to hypotheses 4 to 9 were discussed: change in evaluations and the correspondence of change in beliefs and evaluations. It turns out that the impact of modelling on attitude, and the insignificant effect on perceived control found in the present research, are reported in a small number of related studies as well. With regard to the second issue, it seems that the simple relation between beliefs and evaluations as assumed in the Ajzen (1991) theory can be elaborated. Particularly in a domain that presses for cooperation between individuals, personal and normative variables can be expected to be related. I now turn to hypothesis 10 and 11 on intentions and behaviour.

- *Hypothesis 10 on intentions: not rejected, indirect effect through attitude and subjective norm*

- *Hypothesis 11 on behaviour: not rejected, under the conditions that 1. the model and behavioural options were at the same level of generality and 2. support for implementation was adequate*

An important point for discussion related to these hypotheses, is that intentions change in the absence of change in perceived control. The Ajzen (1991) model proposes that intentions are influenced by attitude, subjective norm and perceived control. The data reported in the previous chapter do not support the proposed relation between perceived control and intention. Perceived control is not a significant independent predictor in either pretest or posttest. The perception of control has a medium correlation to subjective norm in both pretest and posttest (and a medium correlation to attitude in the posttest). The unexpected results for control beliefs can be related to the difficulty of predicting complex behaviours that require resources, cooperation and skills (Eagly and Chaiken, 1993: 182). Ajzen's (1991) extension of the original formulation of the theory of reasoned action is the addition of perceived behavioural control. Although this formulation leads to better predictions of behaviours that are not completely volitional, Ajzen seems to have paid less attention to cooperation with other persons. If cooperation is needed in implementation of an action, a mutual influence of control and normative aspects can be expected.
There are few applications of the theory in settings that emphasise cooperation. In the following table several studies on organisational behaviour are listed: a study on intention to benchmark, a management game on customer orientation and a management game on entrepreneurship.

| *Study* | *Behaviour* | *Regression intention on perceived behavioural control* |
|---|---|---|
| Hill, Mann and Wearing (1996) | benchmarking | beta=.03 not significant |
| Rouwette et al. (1998) | customer focus | B=.08 not significant (pretest)<br>B=.01 not significant (posttest) |
| Rouwette et al. (2003)[45] | entrepreneurship | B=.03 not significant (pretest) |
| Present study | various | B=.09 not significant (pretest)<br>B=.16 not significant (posttest) |

*Table 8.2 Relations between subjective norm and perceived control, and regression of perceived intention on perceived behavioural control*

[45] The original study reports data on 200 respondents. Since data are incomplete on a number of respondents, that table reports correlations and regression for 140 respondents only.

As the table shows, in all instances the regression of intention on perceived behavioural control is nonsignificant. In conclusion, in settings where cooperation is necessary perceived control does not seem to have a separate influence on intentions.

In a recent review, Ajzen (2001) describes a number of studies that point to a modification of perceived behavioural control. These studies make a distinction between perceived controllability (whether people believe they have volitional control over performing a behaviour) and perceived difficulty (self-efficacy) of performing a behaviour. Only perceived difficulty adds significantly to the prediction of intentions and behaviour. Further research is needed to examine the role of perceived controllability and perceived difficulty in an organisational context, and the relation of these concepts to cooperation. This concludes the section on the conceptual model. The following section addresses the measurement procedure.

## 8.3 Measurement method

This section focuses on the benefits and shortcomings of the measurement method followed in this study. A number of suggestions for improvements are given, which remain in the paradigm of social psychological research. (Section 8.5 discusses additional ideas for research that go beyond this orientation.) The measurement method followed in the present study relied to a great extent on standard social psychological operationalisations and data gathering techniques. Beliefs, evaluations, intentions and behaviour were defined in line with the theory of planned behaviour (Ajzen, 1991). Two theories (Petty and Cacioppo, 1986; Chaiken et al., 1989) were used to define variables related to persuasion. These variables were measured using a questionnaire, administered before and after the group model building intervention. Furthermore, interviews with participants were held after the intervention. In these interviews changes assessed on the basis of the questionnaires were checked. In addition, the interviews captured participants' own interpretation of the problem, the intervention process and its outcomes. The combination of traditional questionnaires and posttest interviews has a number of beneficial consequences, but suffers some drawbacks as well. In the following, benefits and suggestions for improvement are discussed in turn.

*Benefits*
The measurement approach followed seems to fit the domain of this study (interventions in messy organisational problems), as can be concluded from the adequate reliability of measurements as well as from the practical applicability of the

approach. The reliability of questionnaire scales is satisfactory[46], while there is a correspondence between questionnaire and interview data with regard to the process elemens and outcome elements at one point in time (but insight into changes over time seems to be limited, see section 7.3.1).
The use of a standard operationalisation and measurement approach increases compatibility of evaluations, intentions and behaviour. In addition, the use of a standard operationalisation and measurement approach makes it possible to compare results found in this domain to the extensive research on the Ajzen (1991) theory and persuasion theories. This is especially relevant since specific cases and corresponding small sample sizes will very likely be the main information source on group model building interventions in the years to come. The approach followed allows aggregation over problems and context of specific group model building projects. In terms of the theory of planned behaviour, this boils down to aggregating results over different attitude objects.
The expected influence of modelling on participants' evaluations and actions can be deduced in a relatively straightforward way, using the coding procedure specified in section 5.4.2.

*Suggestions for improvements*
In the interviews some respondents indicate that they found it difficult and time consuming to fill out the questionnaires before and after the intervention. As indicated in section 5.3.1 the difficulties of field research have not gone unnoticed in the literature. With the above benefits of the approach in mind, it seems useful to keep the general approach intact but to try to lower the time asked from respondents as much as possible. There are a number of alternatives for shortening the questionnaires:

- Measure problem importance at one point in time, as measurements in pretest and posttest show a high correspondence. If the perception of problem importance changes over the intervention (see last section) this is better assessed in an open question in the interview.
- Measure two (instead of three or four) attitude objects.
- Limit the number of beliefs for each evaluation to three or four.

However, the number of items measuring subjective norm can be increased from one to two. In addition it seems worthwhile to maintain the ability to confront quantitative (questionnaire) to qualitative (interview) data. This offers a way to identify unexpected effects of the intervention, on behavioural options not identified before or on additional effects. More important, this allows a check on the subjective

[46] With the exception of perceived behavioural control in the pretest.

interpretation of information (Scheper, 1991) and prevents relying too much on interpretations by an outside observer.

It seems useful to try to specify persuasion variables to the level of specific options. If only two attitude objects are assessed in the questionnaire, it becomes easier to ask participants (in the interviews) whether a specific option was addressed in the sessions. In the following, possible ways to improve the intervention are discussed.

## 8.4 Intervention

This section addresses suggestions for improvements in group model building that follow from the present study. Four areas for improvements stand out:

1. ensure that the problem is important to participants;
2. relate modelling conclusions to participants' insights;
3. support behavioural change by means other than insights alone;
4. tailor group model building to specific problem and organisational contexts.

*Ensure that the problem is important to participants*

An important part of modelling is the analysis of structure – behaviour relations, which emphasises close scrutiny of information. According to theories of persuasion discussed previously (Petty and Cacioppo, 1986; Chaiken et al., 1989) ideas and evaluations may change in two ways: on the basis of information and arguments, or on the basis of peripheral cues (e.g. number of arguments, whether the source is considered an expert). It seems clear that modelling favours the first route and from the results reported in the previous chapter, it appears that modelling results in persuasive arguments (see section 7.3.1)[47]. According to Petty and Cacioppo (1986), attitude change due to persuasive arguments is stable and predictive of behaviour. However, the persuasion theories also stress that subjects will only consider arguments if the issue is of sufficient importance to them. Therefore, it seems that if modellers want to enhance participants' learning and change in evaluations, participants will have to feel the problem being modelled is important.
System dynamicists have long stressed the need to focus on important problems, but in doing so only indirectly referred to learning effects. Forrester (1961: 449) emphasises that only a focus on major issues may yield major rewards. Roberts (1978: 79) sees problem importance as a way to grasp the client's attention for the

[47] This is not to say that modelling does not have an influence on peripheral cues. Section 8.2.1 discusses the influence of peripheral cues. The focus in this study was however on the central route, and peripheral influences were not measured extensively.

modelling effort and recommendations (Roberts, 1978: 79, see section 5.4.5). The persuasion models allow us to specify these statements: if participants feel the issue is not sufficiently important, learning effects may be absent and thus implementation of modelling conclusions hampered.

*Relate modelling conclusions to participants' insights*

In order for arguments to change participants' ideas or evaluations, they have to include relevant and new information (Petty and Cacioppo, 1986; Chaiken et al., 1989). Model builders therefore need to ensure that participants have a clear grasp of the impact of recommendations on topics of importance to them (relevance). So, apart from selecting an important topic, the relation of conclusions to the topic must be clear as well. This makes it necessary to phrase the conclusions of modelling in terms that are understandable to participants and test how recommendations are interpreted. Also, the way in which modelling outcomes contradict participant's ideas (new information) needs to be highlighted. Without stressing the fact that new information is generated, participants may reconcile modelling outcomes with existing mental models without fully realising inconsistencies between the two (see the discussion on participant's insight in own learning in section 7.3.1).

Again, although the role of relevant and new information is discussed in the system dynamics community, its exact contribution to learning effects is unclear. Forrester (1975) discusses the role of counterintuitive insights in changing mental models. Richmond (1997, section 2.3.6) asks participants to publicly state their expectations before model runs are shown. Andersen et al. (1994) propose to restate modelling conclusions in the form of strategic insights or design logic, which underlines the relevance of information because it is clearly connected to system management. Other ways to stress relevant and new aspects of a project's recommendations may be thought of, some of which are discussed below. It seems clear that if the objective is to change ideas and evaluations, conclusions of a modelling project need to go beyond a detailed description of system structure and behaviour.

*Support behavioural change by means other than insights alone*

Although the modelling projects reported in this study seem to have resulted in a number of insights that are relevant and new to participants, two further goals were not met: modelling did not in itself lead participants to change their daily routines and failed to have an impact of perceptions of control. Section 7.5.4 showed that conclusions formulated at a general level fail to have an impact on day-to-day decisions. Intuitively it seems clear that there is a large gap between the abstract insights gained in modelling and concrete changes in a participant's behaviour or organisational policies. Research in social psychology suggests that in order to change behaviour, very specific guidelines with regard to implementation need to be given (cf. Gollwitzer and Bargh, 1996). In an organisational context, Schein (1987) suggests that changes in individual behaviour will not be maintained if they do not lead to changes in habits or are embedded in changes in relevant social networks. Eden (1992d) also points to the importance of social networks for change in participant's orientation to the problem. Section 7.4 showed that participants do not always feel that all relevant groups are present in the modelling sessions. This suggests that participants need more than mere information, even if this information impacts important attitudes and perceived norms.

The sessions in this research also fail to have an impact on perceived behavioural control. As section 8.2.2 shows, a comparable result is found in several other studies on group model building and simulation gaming. A possible explanation is the fact that normative and control elements are closely intertwined in an organisational setting (see chapter seven and section 8.2.2). However, since perceived control adds little to the prediction of behavioural intentions (see appendix D table 13 and 14), one might argue that it is not useful to try to improve participants' perception of control over the problem. Nevertheless there seem to be clear benefits in increasing perceived control in group modelling interventions. Several case descriptions in chapter six illustrate how participants wait for one another before implementing conclusions: although important insights are gained in the modelling sessions, more is needed before participants turn to implementation. These results are in line with the suggestions on implementation in the literature described above and point to the importance of perceived behavioural control. Therefore it seems worthwhile to try to adjust the intervention so that its impact on perceived control increases.

The literature on interventions in messy problems suggests several ways to increase the impact on on perceived control and daily routines. Two suggestions are the following. First, at the close of a modelling intervention, a contingency plan might be drawn (Mason and Mitroff, 1981) which details how the recommendations can be implemented. Second, implementation plans (e.g. the Technology of Participation methods, cf. Spencer, 1996) might be developed that specify the time path and responsibilities for implementation. Contingency plans and implementation plans serve to make modelling recommendations more specific and clarify their impacts on daily work.

*Tailor group model building to specific problem and organisational contexts*

Apart from increasing the impact of model building as a whole, there are additional benefits in adjusting the method to specific problem and organisational situations. This is in line with Pawson and Tilley's (1997) idea of a context – mechanism – outcome configuration, as well as the idea of scripts for modelling (Andersen and Richardson, 1997). Basically this means that system dynamicists accept the idea that the intervention works differently for different target groups. In a very political context the main benefit of modelling might be the separation of differences in interpretation from differences in goals (cf. Vennix, 1996). If this is fully accepted, the intervention might focus more clearly on identification of differences in terminology used and facilitation of the communication process. This connects to the discussion on modelling formats in section 2.3.6. Although the main differences between modelling approaches, quantification and model size, turn out to have a lower impact on outcomes than expected, other modifications of group model building are conceivable. A combination of system dynamics and cognitive mapping (Lane, 1994; Eden, 1992b, see section 2.3.6) emphasises a careful elicitation of individual mental models and thereby might point out differences in interpretation earlier in the process. In addition, it is not very clear in which sort of situations the facilitator's role is particularly important, as the contribution of the facilitator to overall results is seldom reported in case descriptions (see chapter three). This points to the benefit of researching the separate elements of group model building in more detail, which is one of the suggestions for future research addressed in the next section.

## 8.5 Further research

In this section avenues for future research are suggested, that go beyond the social psychological orientation discussed in section 8.3

The first goal for future studies might be to find commonalities between group model building approaches and to try to find the essential elements of the method. Which elements are necessary to produce insight or consensus? This can be researched by 'stripping' the intervention, i.e. by leaving out a specific element and assessing how this changes results. Research into psychological therapies is relevant in this regard. An analogy can be drawn between group model building as an intervention in an organisational context, and psychological therapies that commonly focus on individuals or small groups. Both interventions focus at creating a helping relationship, and the process facilitation approach used in modelling resembles certain nondirective therapies (Rouwette, 1992). A further similarity of both interventions is their complexity: changes that occur after the intervention can be contributed to many different elements: the facilitator or therapist, the client's readiness for change or the contributions of a specific approach to name but a few. Studies on the effectiveness of therapies frequently aim at finding out the contribution of specific intervention elements. With regard to modelling, the impact of facilitation can for instance be assessed by comparing a modelling intervention supervised by a chairman (who participates actively in the discussions) to an intervention supervised by a facilitator (who remains neutral with regard to content).

Another interesting topic in this regard is the role of detailed knowledge on the problem. Group model building, by focussing on the relation between structure and behaviour, can be said to transfer large amounts of detailed information on the problem being modelled. However, one hypothesis on why modelling works (Andersen et al., 1997: 195) is the chunking hypothesis: 'What matters is getting big chunks of insight – the details that lead up to the insights are largely means to acquire group confidence and are forgotten'. The question is therefore whether the stage of gathering detailed information can be bypassed, and if so, at which costs. An alternative to modelling is not to focus on problem elements, but only to consider information which is necessary to compare decision alternatives. 'Minimal' methods which operate on this assumption are the functional method (Vriens, 1998: 368) and participative Multi-Criteria Analysis (Rush, 2000). Facilitation and detailed information are only two examples of a host of group model building elements that might be discerned. By leaving out intervention elements one by one, and comparing these to the effect of the 'full' intervention on specific goal variables, we might increase or understanding how the intervention works. In this way it might be possible to disentangle the intervention from other context factors, and identify more specific context – mechanism – outcome configurations.

A second aim that seems promising is to research the impact on beliefs constellations in more detail. Triangulation of methodologies can provide further insights into the influence of modelling on mental models, including evaluations. This can be done by researching the impact on cognitive maps in more restricted interventions (cf. Vennix, 1990). Alternatively, subjective interpretations can be studied by using paired comparisons (Thurstone, 1927) as is done in a modelling context by Frost-Kumpf et al. (2001). The approach advocated by Scheper (1991; Scheper and Faber, 1994) probes the meaning of constructs in a mental model and thereby provides additional information on mental model content. There seems to be a place for more qualitative research into group model building using a grounded theory approach (Glaser and Strauss, 1967). Burt (2000) uses this approach to investigate the impact of scenario development on organisational change.

Third, future studies might incorporate group and organisational factors in addition to individual variables (also mentioned by Vennix, 1990). As shown by the study of Hickson et al. (1986), organisational variables have an influence on decision making processes in management teams. More insight into the effect of group and organisational variables allow us to adjust group model building interventions better to contextual conditions.

Fourth, this study and the proposed directions for future studies mentioned above, involve a multitude of interrelated variables. It is likely that further development and testing of theories can benefit from formal modelling (cf. Hanneman, 1988). In addition to empirical research, formal modelling might shed further light on the complex interactions of variables in group decision making.

In conclusion, the present study described how group model building in some respects can be understood as a process of mutual persuasion. Participants in modelling sessions change their evaluations on the basis of information generated by other participants and structured in a model. The hope is that the attempt in the present study may lead to further research, leading to a better understanding of this type of interventions and to an improved way of dealing with complex problems.

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*Appendix A*

## Cases meta analysis


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*Appendix B*

# Operationalisation of variables

| *Variable* | *Data gathering method* | *Variable construction* |
|---|---|---|
| **Context** | | |
| 1. Client organisation* | Interview gatekeeper | Organisation sort, sector and size |
| 2. Problem complexity* | Content analysis | Qualitative: analytical and social complexity (cf. Hickson et al., 1986) |
| 3. Motivation to process information | Questionnaire | Scale of two items on importance to organisation<br>Two separate items on importance to individual |
| 4. Ability to implement conclusions | Interview participant<br>Content analysis | Qualitative<br>Qualitative |
| 5. Age | Questionnaire | One item |
| 6. Years working with organisation | Questionnaire | One item |
| **Mechanism** | | |
| 7. Participant characteristics* | Interview gatekeeper | Number and function |
| 8. Consultant* | Observation | Name consultant organisation |
| 9. Duration* | Content analysis | Time involvement of participants and project duration |
| 10. Techniques employed in the intervention* | Observation | Qualitative |
| 11. Model characteristics* | Observation | Model size, qualitative or quantitative model, use of a preliminary model |
| 12. Persuasive content | Content analysis<br>Interview participant | Coding procedure<br>Qualitative check by participants |
| 13. Ability to process information | Questionnaire | Scale of six items (cf. Rouwette et al. 1997)<br>Two separate items on dominance and time pressure<br>Two items on overall success and efficiency |
| 14. Evaluation in comparison to control group | Questionnaire | Scale of seven items (cf. Vennix et al., 1993) |
| 15. Intervention elements | Questionnaire | Eight items (cf. McCartt and Rohrbaugh, 1989; Vennix et al., 1993) |
| 16. Argument quality | Questionnaire<br>Interview participant | Scale of nine items (cf. Janis and Mann, 1977)<br>One separate item on costs<br>Qualitative |

| Outcome | | |
|---|---|---|
| 17. Conclusions/ dissemination* | Interview gatekeeper | Qualitative |
| 18. System changes* | Interview gatekeeper | Qualitative |
| 19. Options* | By researcher/ Questionnaire | Two to four items identified by problem analysis/<br>Two to four items in open question pretest |
| 20. Attitude towards behaviour | Questionnaire | Scale of two items (cf. Madden et al., 1992) |
| 21. Subjective norm | Questionnaire | One item (cf. Ajzen and Fishbein, 1980) |
| 22. Perceived behavioural control | Questionnaire | Scale of two items (cf. Madden et al., 1992) |
| 23. Beliefs | Questionnaire<br>Interview participant | Scale of three to seven items<br>Self-generated/ researcher<br>Normative belief: open question |
| 24. Intention | Questionnaire | Scale of two items (cf. Madden et al., 1992) |
| 25. Behaviour* | Interview gatekeeper | Qualitative |

*Table 1. Appendix B (repeated from table 5.6): Data sources and construction of variables ("/" indicates alternative options with regard to variable construction)*

Items that are measured qualitatively are indicated with *. All questionnaire items are measured in a five point Likert format, unless otherwise indicated. The coding of questionnaire items is indicated in the following in **[bold]**. The scores on the questionnaire items are reported in the datamatrix in appendix E.

## Context

*1. Client organisation (interview gatekeeper)**
Organisation sort: profit, non-profit or governmental.
Sector: e.g. finance, information services.
Size: number of employees working with organisation or department.

*2. Problem complexity (content analysis)**
Measured using the elements of analytical and social complexity, distinguished by Hickson et al. (1986: 267).

Analytical complexity

- Rarity: frequency with which similar matters occur.

- Radicality of consequences: how far the decision changed things.
- Seriousness of consequences: how serious it would be for the organisation if things went wrong.
- Diffusion of consequences: how widespread were the decision's effects.
- Endurance of consequences: how far ahead people looked when making the decision.
- Precursiveness: how far the decision was likely to set parameters for subsequent decisions.
- Number of interests involved: number of internal and external units named as having been involved.
- Diversity of interests involved: variety of interests.
- Openness to alternatives: how far was there a feeling that the decision had already been made.

Social complexity

- Pressure of influence: how great a weight of influence was exerted.
- Intervention: how far external influence was exerted.
- Imbalance: how far the total pressure was uneven across interest units.
- Contention of objectives: how far the interest units that exerted influence did so in opposite directions.

*3. Motivation to process information (questionnaire pretest and posttest, scale of two items on importance to organisation in pretest and posttest, two separate items on importance to individual)*

How important is this problem to your organisation? very important - very unimportant **[impo]**

How important is this problem to you personally? very important - very unimportant **[impi]**

*4. Control over implementation (interview participant, content analysis)*

Interview: to which extent can you set priorities in the problem?

Documents: match between action identified and the participant's function and responsibities **[implem]**.

*5. Age (questionnaire posttest, one item)*

What is your year of birth? **[ybirth]**

*6. Years working with organisation (questionnaire posttest, one item)*

In which year have you started working with this organisation? **[yorg]**

**Mechanism**

*7. Participant characteristics (interview gatekeeper)**
Number of participants in sessions.
Function of participants in sessions.

*8. Consultant (observation)**
Name consultant organisation.

*9. Duration (content analysis)**
Time involvement of participants in hours (sessions, workbooks and data gathering).
Project duration in months, from initial client contact to project close.

*10. Techniques employed in the intervention (observation)**
Which techniques were used in the modelling sessions: individual interviews, Nominal Group Technique (NGT), flow model, causal loop diagram (CLD), data gathering, graph estimation, discussion model runs, workbooks.

*11. Model characteristics (observation)**
Use of a preliminary model: no, flow model, fully quantified model.
Type of model: qualitative or quantitative; small or large.

*12. Persuasive content (content analysis, interview participant)*
Coding procedure, see section 5.4.2. Two formats: a. content analysis and b. by participants in interview. Section 5.5.1 reports on the reliability of the coding procedure **[chcat]**.
Interview questions (similar to argument quality):

- did the sessions provide information relevant to your work?
- are the changes from pretest to posttest recognizable?
- are the changes from pretest to posttest due to the sessions or to other developments?

*13. Ability to process information (questionnaire posttest, scale of six items, interview participant)*
The modelling sessions were characterised by:

- open communication **[opencom]**;
- clear and understandable communication **[clearcom]**;
- equal participation **[eqpart]**;
- ample opportunity to raise issues about which opinions were divided **[amopp]**;

- pragmatic and clear focus **[pragm]**;
- attention to ideas and opinions **[attidea]**.

Two separate items on dominance **[domin]** and time pressure **[timepr]**.

Two separate items on efficiency **[effic]** and overall success **[success]**:

- Using modelling in approaching the problem is efficient: strongly agree – strongly disagree.
- All in all I think these meetings were successful: strongly agree – strongly disagree.

All questions could be answered from strongly agree to strongly disagree.

Three interview questions relate to ability to process information:

- whether participants know or have worked with other participants in the sessions;
- prior expectations of the sessions;
- what event related to the sessions stood out in their memory.

*14. Evaluation in comparison to control group (questionnaire posttest, scale of seven items, two separate items)*

If you compare these meetings using different techniques (such as causal diagrams), with normal meetings or conferences in which you discuss similar problems, would you say these meetings:

- give *more* insight compared to normal meetings? **[mins]**
- give insight compared to normal meetings *more quickly*? **[qins]**
- result in a *better* communication between participants? **[mcommun]**
- give rise to a shared vision between participants *more quickly*? **[qcons]**
- give rise to a *better* shared vision between participants? **[bcons]**
- give rise to commitment of participants *more quickly*? **[qcommit]**
- give rise to *more* commitment of participants? **[mcommit]**

All questions could be answered from strongly agree to strongly disagree.

*15. Intervention elements (questionnaire posttest, eight items)*

The meetings consisted of several elements which may have contributed in different ways to the overall effect of the meetings. In the following questions you are asked to specify how much each element contributed to the overall effect:

- the fact that the diagrams were projected/ recorded in a way that was visible to everybody **[proj]**;
- the fact that an outsider was accompanying as a 'group facilitator' **[facilit]**;
- the opportunity for open and extensive discussion **[oppdisc]**;
- the use of causal loop diagrams **[diagram]**;
- parameter estimation **[param]**;
- analysis of the model **[modanal]**;

- data analysis **[datanal]**;
- analysis of model output **[outanal]**.

All questions could be answered from -5 (was of no use whatsoever, obstructed the sessions) to +5 (contributed very much).

*16. Argument quality (questionnaire posttest, scale of nine items, one separate item, interviews)*

- in the meetings all relevant options were addressed **[aloption]**;
- in the meetings all relevant goals were addressed **[algoal]**;
- in the meetings all relevant values were addressed **[alvalue]**;
- in the meetings all relevant risks were addressed **[alrisk]**;
- in the meetings all important information for weighing alternative options was addressed **[alinfo]**;
- the recommendations were reached on the basis of an integration of all relevant information **[alinteg]**;
- the recommendations were reached on the basis of an evaluation of all positive and negative outcomes **[aloutc]**;
- in formulating options all relevant conditions were taken into account **[alcond]**;
- in formulating options all relevant contingencies were taken into account **[alcont]**.

The separate item on costs is the following:
in the meetings all relevant costs were addressed **[alcost]**.
All questions could be answered from strongly agree to strongly disagree.

Interviews:

- have all relevant actions been identified?
- did the sessions provide information relevant to your work?
- are the changes from pretest to posttest recognizable?
- are the changes from pretest to posttest due to the sessions or to other developments?

## Outcome

*17. Conclusions/ dissemination (interview gatekeeper)**

How conclusions were disseminated across larger groups in the organisation, e.g. in a report or flight simulator, and if applicable to which groups (e.g. higher management level).

*18. System changes (interview gatekeeper)**
To which extent conclusions were implemented and how.

*19. Options (by researcher/ questionnaire pretest and posttest)**
Behavioural options are either specified by the researcher or measured in a free format, i.e. participants are asked to define relevant options for themselves.

*20. Attitude towards action (questionnaire pretest and posttest, scale of two items)*
Implementing option 1 in [time period of concern] is very beneficial – very harmful **[attb]**.
Implementing option 1 in [time period of concern] is very good – very bad **[attg]**.

*21. Subjective norm (questionnaire pretest and posttest, one item)*
Most people who are important to me, think that I should implement option 1 in [time period of concern] strongly agree – strongly disagree **[norm]**.

*22. Perceived behavioural control (questionnaire pretest and posttest, scale of two items)*
Implementing option 1 in [time period of concern] is very easy – very difficult **[conte]**.
The number of events that could keep me from implementing option 1 in [time period of concern] is very large – very small **[contn]**.

*23. Beliefs (questionnaire pretest and posttest, two to seven items, posttest open question, interview participant)*
For each belief, strength and evaluation are measured with one question each (see section 5.4.3). Beliefs are self-generated by respondents or specified in closed format questions by the researcher. Examples of closed format questions on (behavioural) belief evaluation and strength are the following.

- Belief evaluation: Please indicate your evaluation of a reduction of the number of travel agencies: very good – very bad.
- Belief strength: Please indicate to which extent option 1 (improve the understanding of the way to do business of each part, creating more loyalty to each other) contributes to this consequence (a reduction of the number of travel agencies): -5 (is very harmful to this consequence ) to +5 (is very beneficial to this consequence) .

As described in section 5.5.2 the score for beliefs is obtained by summarising the product of belief strength and evaluation over all beliefs. Appendix E reports scores for behavioural beliefs **[optag]**, normative beliefs, **[optsng]** and control beliefs **[optpcg]**.

With regard to normative beliefs, a question on important referents is included in the posttest: who would you ask for information about the problem modelled in the sessions? In the interviews respondents are asked whether all stakeholders and areas of expertise were present in the modelling sessions.

*24. Intention (questionnaire pretest and posttest, scale of two items)*
I intend to implement option 1 in [time period of concern] **[inti]**.
I will make an effort to implement option 1 in [time period of concern] **[inte]**.

*25. Behaviour (interview gatekeeper, content analysis)**
Interview:
- have any changes in working behaviour occurred?
- to which extent were conclusions taken up by participants?

Content analysis: reported changes with regard to actions identified in questionnaires.

*Appendix C*

## Pretest and posttest questionnaire

**Please do not fill out this page**

**respondent number**

| | | | | |
|---|---|---|---|---|
| | | | | |

# Questionnaire

# Pretest

| | |
|---|---|
| | date arrival |
| | control |
| | coding |

Methodology Section, Nijmegen School of Management, Nijmegen University
March 2003

Dear participant,

You are about to participate in a number of sessions facilitated by members of the Nijmegen School of Management of Nijmegen University. In these sessions we will use the group model building method. With this questionnaire we aim to further improve the modelling sessions. This evaluation has two goals: a. to assess the extent to which the sessions are successful in reaching their goals, and b. to tailor the sessions to participants′ expectations. The outcomes of this evaluation will be incorporated in the design of future sessions. Your cooperation will be greatly appreciated. This questionnaire is the first part of the evaluation; the second part is a posttest and will be handed out after the modelling sessions.

All answers will be treated confidentially. In order to ensure a correct interpretation of your answers, it is possible that you will be asked for additional comments to specific questions at a later time. For this reason you will be asked to fill out your name. However, the answers to this evaluation will be processed anonymously.

Thank you for your cooperation in the evaluation procedure.

## Instructions

Most questions can be answered using the printed response categories. You can give your answer to these questions by checking the response of your choice.
If you are asked to indicate a number, please note your answer in the space provided. Please fill out one digit per box.
Please answer open questions, indicated by the printed lines, by writing down you comments.
The questionnaire contains a number of statements, about which your opinion is asked. A limitation of the use of a questionnaire is that the statements and response categories can not cover the full range of individual standpoints in detail. Please answer the questions by checking the answer that corresponds most closely to your opinion, even if your opinion is not represented in detail.

**Background**

1. Name:

_______________________________________________

2. What is your year of birth?

| 1 | 9 | | |
|---|---|---|---|

3. Via which organisation are you involved in this project?

_______________________________________________

_______________________________________________

_______________________________________________

4. In what year did you start working for the organisation mentioned in the previous question?

| 1 | 9 | | |
|---|---|---|---|

5. What is your main task or responsibility in this organisation, and what are your additional tasks or responsibilities?

_______________________________________________

_______________________________________________

_______________________________________________

_______________________________________________

_______________________________________________

_______________________________________________

_______________________________________________

In the modelling sessions you are going to participate in, a number of strategic options for your organisation will be discussed. The questions in the following section address your personal ideas and expectations about these strategic options. We are interested in your *personal* point of view, and there is no correct or incorrect answer.

In the modelling sessions we will mainly be addressing the following subject.

| |
|---|
| [subject] |

What would you like to achieve with regard to [subject] in [time period of concern]?

There is a number of ways to bring the desired situation with regard to [subject] closer. In which way can your own organisation contribute to this? Please describe three ways in which *according to you* your organisation can contribute to the [desired situation], in [time period of concern].

Option 1.

Option 2.

Option 3.

The following questions address the three options noted down in the previous question.

| | | | | | |
|---|---|---|---|---|---|
| 1. I intend to implement option 1 in [time period of concern]. | strongly agree o | agree o | agree/ disagree o | disagree o | strongly disagree o |
| 2. I intend to implement option 2 in [time period of concern]. | strongly agree o | agree o | agree/ disagree o | disagree o | strongly disagree o |
| 3. I intend to implement option 3 in [time period of concern]. | strongly agree o | agree o | agree/ disagree o | disagree o | strongly disagree o |

| | | | | | |
|---|---|---|---|---|---|
| 4. Implementing option 1 in [time period of concern] is | very beneficial o | beneficial o | neutral o | harmful o | very harmful o |
| 5. Implementing option 1 in [time period of concern] is | very good o | good o | neutral o | bad o | very bad o |
| 6. Implementing option 2 in [time period of concern] is | very beneficial o | beneficial o | neutral o | harmful o | very harmful o |
| 7. Implementing option 2 in [time period of concern] is | very good o | good o | neutral o | bad o | very bad o |
| 8. Implementing option 3 in [time period of concern] is | very beneficial o | beneficial o | neutral o | harmful o | very harmful o |
| 9. Implementing option 3 in [time period of concern] is | very good o | good o | neutral o | bad o | very bad o |

| | | | | | |
|---|---|---|---|---|---|
| 10. Most people that are important to me, think that I should implement option 1 in [time period of concern]. | strongly agree o | agree o | agree/ disagree o | disagree o | strongly disagree o |
| 11. Most people that are important to me, think that I should implement option 2 in [time period of concern]. | strongly agree o | agree o | agree/ disagree o | disagree o | strongly disagree o |

| | | | | | |
|---|---|---|---|---|---|
| 12. Most people that are important to me, think that I should implement option 3 in [time period of concern]. | strongly agree o | agree o | agree/ disagree o | disagree o | strongly disagree o |

| | | | | | |
|---|---|---|---|---|---|
| 13. Implementing option 1 in [time period of concern] is | very easy o | easy o | neutral o | difficult o | very difficult o |
| 14. The number of events that could keep me from implementing option 1 in [time period of concern], is | very large o | large o | neutral o | small o | very small o |
| 15. Implementing option 2 in [time period of concern] is | very easy o | easy o | neutral o | difficult o | very difficult o |
| 16. The number of events that could keep me from implementing option 2 in [time period of concern], is | very large o | large o | neutral o | small o | very small o |
| 17. Implementing option 3 in [time period of concern] is | very easy o | easy o | neutral o | difficult o | very difficult o |
| 18. The number of events that could keep me from implementing option 3 in [time period of concern], is | very large o | large o | neutral o | small o | very small o |

| | | | | | |
|---|---|---|---|---|---|
| 19. I will try to implement option 1 in [time period of concern]. | strongly agree o | agree o | agree/ disagree o | disagree o | strongly disagree o |
| 20. I will try to implement option 2 in [time period of concern]. | strongly agree o | agree o | agree/ disagree o | disagree o | strongly disagree o |
| 21. I will try to implement option 3 in [time period of concern]. | strongly agree o | agree o | agree/ disagree o | disagree o | strongly disagree o |

*The questions on this page address possible consequences of your actions with regard to [subject].*

In their work, people often try to achieve certain outcomes while avoiding others. University staff, for example, could be trying to achieve a 'high quality education'. A consequence that is avoided could be a decline of the number of students graduating per year.
What are the most important consequences of your work that you will focus on in [time period of concern]?
(If you describe a development over time, please indicate the expected direction of the development. For example, refer to 'decline in the number of students graduating' instead of 'number of students graduating'.)

Consequence 1.

Consequence 2.

Consequence 3.

Please indicate your evaluation of these consequences.

| | very good | good | neutral | bad | very bad |
|---|---|---|---|---|---|
| Consequence 1 | o | o | o | o | o |
| Consequence 2 | o | o | o | o | o |
| Consequence 3 | o | o | o | o | o |

Please indicate to which extent you expect the three strategic options (see page 4) to contribute to these consequences. Please give your answer on a scale of –5 to +5, indicating:

-5 = is very harmful to this consequence;
0 = is not harmful, but not beneficial to this consequence either;
+5 = is very beneficial to this consequence.

For example, if you fill out +5 after consequence 1 in the first column (see the following table), you indicate that you expect option 1 to contribute very strongly to consequence 1.

| | Option 1 | Option 2 | Option 3 |
|---|---|---|---|
| Consequence 1 | | | |
| Consequence 2 | | | |
| Consequence 3 | | | |

*The questions below address individuals or groups whose opinion is important in your work.*

Members of an organisation rarely decide what to do in their work on the basis of their individual preferences only. Mostly the opinion of one or more other individuals or groups is taken into account in making a decision. For example, in a decision on the courses to be given in a university, the opinion of students is taken into account as well.
In your work in [time period of concern] you will weigh the opinions of certain individuals or groups more heavily than the opinions of others. The opinions of

which individuals or groups do you think is most important in deciding what to do in your work in [time period of concern]?
(Individuals or groups can be operating within or outside of your own organisation.)

Individual/ group 1.

Individual/ group 2.

Individual/ group 3.

Please indicate the extent to which you follow the opinions of these groups or individuals in your work.

| | completely | to a large extent | neutral | partly | not at all |
|---|---|---|---|---|---|
| Individual/ group 1 | o | o | o | o | o |
| Individual/ group 2 | o | o | o | o | o |
| Individual/ group 3 | o | o | o | o | o |

Please indicate to which extent you think these individuals or groups would want you to implement the three options (see page 4). Please give your answer again on a scale of –5 to +5, indicating:

-5 = is strongly opposed to me implementing this option;
0 = does not have an opinion on whether I implement this option or not;
+5 = is strongly in favour of me implementing this option.

For example, if you fill out +5 after individual or group 1 in the first column (see the following table), you indicate that you think individual or group 1 is strongly in favor of you implementing option 1.

| | Option 1 | Option 2 | Option 3 |
|---|---|---|---|
| Individual/ group 1 | | | |
| Individual/ group 2 | | | |
| Individual/ group 3 | | | |

*The following questions address opportunities and threats to the options identified before.*

In an organisation situations or developments can occur that hamper or, alternatively, facilitate a planned policy. In a university, for example the job opportunities in a specific field are an important determinant of the number of students starting their studies in this field.
Which three situations or developments are the most influential for your actions with regard to [subject]?
(If you describe a development over time, again please indicate the expected direction of the development. For example, refer to 'decrease in job opportunities' instead of 'job opportunities'.)

Situation/ development 1.

Situation/ development 2.

Situation/ development 3.

Please indicate your estimation of the likelihood that these situations or developments will manifest themselves in [time period of concern].

| | very likely | likely | neutral | unlikely | very unlikely |
|---|---|---|---|---|---|
| Situation/ development 1 | o | o | o | o | o |
| Situation/ development 2 | o | o | o | o | o |
| Situation/ development 3 | o | o | o | o | o |

Please indicate whether these situations or developments present an opportunity or threat for the options identified before (see page 4). Please give your answer again on a scale of –5 to +5, indicating:

-5 = makes the implementation of this option very difficult;
0 = has no influence on the implementation of this option;
+5 = makes the implementation of this option very easy.

For example, if you fill out -5 after situation/ development 1 in the first column (see the following table), you indicate that you think situation/ development 1 makes the implementation of option 1 very difficult.

| | Option 1 | Option 2 | Option 3 |
|---|---|---|---|
| Situation/ development 1 | | | |
| Situation/ development 2 | | | |
| Situation/ development 3 | | | |

Please indicate the importance of [subject] for your organisation.

| | very important | important | neutral | unimportant | very unimportant |
|---|---|---|---|---|---|
| The [subject] is for my organisation | o | o | o | o | o |

Please indicate the importance of [subject] to you personally.

| | very important | important | neutral | unimportant | very unimportant |
|---|---|---|---|---|---|
| The [subject] is to me personally | o | o | o | o | o |

If the researcher conducting this evaluation needed further information on the policy of your organisation with regard to [subject], to whom would you refer him?
(Please note down one or more persons working within or outside of your organisation.)

______________________________________________

______________________________________________

______________________________________________

______________________________________________

If you needed further information on the policy of your organisation with regard to [subject], who would you consult yourself?
(Please note down one or more persons working within or outside of your organisation.)

______________________________________________

______________________________________________

______________________________________________

______________________________________________

By whom are you yourself consulted on the on the policy of your organisation with regard to [subject]?
(Please note down one or more persons working within or outside of your organisation.)

Which other sources of information do you consult on the policy of your organisation with regard to [subject]?

*End of the questionnaire. Thank you again for your cooperation.*

**Please do not fill out this page**

**respondent number**

| | | | | |
|---|---|---|---|---|
| | | | | |

# Questionnaire

# Posttest

| | |
|---|---|
| | date arrival |
| | control |
| | coding |

Methodology Section, Nijmegen School of Management, Nijmegen University
November 2003

Dear participant,

You have participated in a number of sessions facilitated by members of the Nijmegen School of Management of Nijmegen University. This evaluation form is the second and last part of the evaluation of the modelling sessions. The evaluation has two goals: a. to assess the extent to which the sessions are successful in reaching their goals, and b. to tailor the sessions to participants' expectations. The outcomes of this evaluation will be incorporated in the design of future sessions. Your cooperation will be greatly appreciated.

All answers will be treated confidentially. In order to ensure a correct interpretation of your answers, it is possible that you will be asked for additional comments to specific questions at a later time. For this reason you will be asked to fill out your name. However, the answers to this evaluation will be processed anonymously.

Thank you for your cooperation in the evaluation procedure.

### Instructions

Most questions can be answered using the printed response categories. You can give your answer to these questions by checking the response of your choice.
If you are asked to indicate a number, please note your answer in the space provided. Please fill out one digit per box.
Please answer open questions, indicated by the printed lines, by writing down you comments.
The questionnaire contains a number of statements, about which your opinion is asked. A limitation of the use of a questionnaire is that the statements and response categories can not cover the full range of individual standpoints in detail. Please answer the questions by checking the answer that corresponds most closely to your opinion, even if your opinion is not represented in detail.

Name:

In the modelling sessions you have participated in, a number of strategic options for your organisation have been discussed. The questions in the following section address your personal ideas and expectations about these strategic options. We are interested in your personal point of view, and there is no correct or incorrect answer. The modelling sessions have mainly addressed the following subject.

| |
|---|
| [subject] |

In order to assess a possible effect of the sessions, we would like to ask you again what you would like to achieve with regard to [subject]in [time period of concern]. Please indicate below what you *currently* think is a desirable situation (with regard to [subject]).

There is a number of ways to bring the desired situation with regard to [subject] closer. In which way do you think *currently* that your own organisation can contribute to this? Please describe three ways in which *according to you* your organisation can contribute to the desired situation, in [time period of concern].

Option 1.

Option 2.

Option 3.

In the meantime you have participated in the modelling sessions, which possibly has affected your ideas and viewpoints about [subject]. We are therefore interested in your opinion currently about the strategic options you filled out in the pretest. We would like to ask you to answer again a number of questions on these strategic options, that were already presented to you in the pretest.

In the pretest you filled out the following three strategic options in which your organisation can contribute to [subject], in [time period of concern].
1.
2.
3.

*The following questions are about these strategic options.*

| | | | | | |
|---|---|---|---|---|---|
| 1. I intend to implement option 1 in [time period of concern]. | strongly agree o | agree o | agree/ disagree o | disagree o | strongly disagree o |
| 2. I intend to implement option 2 in [time period of concern]. | strongly agree o | agree o | agree/ disagree o | disagree o | strongly disagree o |
| 3. I intend to implement option 3 in [time period of concern]. | strongly agree o | agree o | agree/ disagree o | disagree o | strongly disagree o |

| | | | | | |
|---|---|---|---|---|---|
| 4. Implementing option 1 in [time period of concern] is | very beneficial o | beneficial o | neutral o | harmful o | very harmful o |

| | | | | | |
|---|---|---|---|---|---|
| 5. Implementing option 1 in [time period of concern] is | very good o | good o | neutral o | bad o | very bad o |
| 6. Implementing option 2 in [time period of concern] is | very beneficial o | beneficial o | neutral o | harmful o | very harmful o |
| 7. Implementing option 2 in [time period of concern] is | very good o | good o | neutral o | bad o | very bad o |
| 8. Implementing option 3 in [time period of concern] is | very beneficial o | beneficial o | neutral o | harmful o | very harmful o |
| 9. Implementing option 3 in [time period of concern] is | very good o | good o | neutral o | bad o | very bad o |

| | | | | | |
|---|---|---|---|---|---|
| 10. Most people that are important to me, think that I should implement option 1 in [time period of concern]. | strongly agree o | agree o | agree/ disagree o | disagree o | strongly disagree o |
| 11. Most people that are important to me, think that I should implement option 2 in [time period of concern]. | strongly agree o | agree o | agree/ disagree o | disagree o | strongly disagree o |
| 12. Most people that are important to me, think that I should implement option 3 in [time period of concern]. | strongly agree o | agree o | agree/ disagree o | disagree o | strongly disagree o |

| | | | | | |
|---|---|---|---|---|---|
| 13. Implementing option 1 in [time period of concern] is | very easy o | easy o | neutral o | difficult o | very difficult o |
| 14. The number of events that could keep me from implementing option 1 in [time period of concern], is | very large o | large o | neutral o | small o | very small o |
| 15. Implementing option 2 in [time period of concern] is | very easy o | easy o | neutral o | difficult o | very difficult o |
| 16. The number of events that could keep me from implementing option 2 in [time period of concern], is | very large o | large o | neutral o | small o | very small o |
| 17. Implementing option 3 in [time period of concern] is | very easy o | easy o | neutral o | difficult o | very difficult o |
| 18. The number of events that could keep me from implementing option 3 in [time period of concern], is | very large o | large o | neutral o | small o | very small o |

| | | | | | |
|---|---|---|---|---|---|
| 19. I will try to implement option 1 in [time period of concern]. | strongly agree o | agree o | agree/ disagree o | disagree o | strongly disagree o |
| 20. I will try to implement option 2 in [time period of concern]. | strongly agree o | agree o | agree/ disagree o | disagree o | strongly disagree o |
| 21. I will try to implement option 3 in [time period of concern]. | strongly agree o | agree o | agree/ disagree o | disagree o | strongly disagree o |

*The questions below address possible consequences of your actions with regard to [subject].*

In their work, people often try to achieve certain outcomes while avoiding others. University staff, for example, could be trying to achieve a 'high quality education'. A consequence that is avoided could be a decline of the number of students graduating per year.
What are the most important consequences of your work that you will focus on in [time period of concern]?
(If you describe a development over time, please indicate the expected direction of the development. For example, refer to 'decline in the number of students graduating' instead of 'number of students graduating'.)

Consequence 1.

______________________________________________
______________________________________________
______________________________________________
______________________________________________

Consequence 2.

______________________________________________
______________________________________________
______________________________________________
______________________________________________

Consequence 3.

Please indicate your evaluation of these consequences.

| | very good | good | neutral | bad | very bad |
|---|---|---|---|---|---|
| Consequence 1 | o | o | o | o | o |
| Consequence 2 | o | o | o | o | o |
| Consequence 3 | o | o | o | o | o |

Please indicate to which extent you expect the three strategic options (see page 4) to contribute to these consequences. Please give your answer on a scale of –5 to +5, indicating:

-5 = is very harmful to this consequence;
0 = is not harmful, but not beneficial to this consequence either;
+5 = is very beneficial to this consequence.

For example, if you fill out +5 after consequence 1 in the first column (see the following table), you indicate that you expect option 1 to contribute very strongly to consequence 1.

| | Option 1 | Option 2 | Option 3 |
|---|---|---|---|
| Consequence 1 | | | |
| Consequence 2 | | | |
| Consequence 3 | | | |

*The following questions address individuals or groups whose opinion is important in your work.*

Members of an organisation rarely decide what to do in their work on the basis of their individual preferences only. Mostly the opinion of one or more other individuals or groups is taken into account in making a decision. For example, in a decision on the courses to be given in a university, the opinion of students is taken into account as well.
In your work in [time period of concern] you will weigh the opinions of certain individuals or groups more heavily than the opinions of others. The opinions of which individuals or groups do you think is most important in deciding what to do in your work in [time period of concern]?
(Individuals or groups can be operating within or outside of your own organisation.)

Individual/ group 1.

Individual/ group 2.

Individual/ group 3.

Please indicate the extent to which you follow the opinions of these groups or individuals in your work.

| | completely | to a large extent | neutral | partly | not at all |
|---|---|---|---|---|---|
| Individual/ group 1 | o | o | o | o | o |
| Individual/ group 2 | o | o | o | o | o |
| Individual/ group 3 | o | o | o | o | o |

Please indicate to which extent you think these individuals or groups would want you to implement the three options (see page 4). Please give your answer again on a scale of –5 to +5, indicating:

-5 = is strongly opposed to me implementing this option;
0 = does not have an opinion on whether I implement this option or not;
+5 = is strongly in favour of me implementing this option.

For example, if you fill out +5 after individual or group 1 in the first column (see the following table), you indicate that you think individual or group 1 is strongly in favor of you implementing option 1.

| | Option 1 | Option 2 | Option 3 |
|---|---|---|---|
| Individual/ group 1 | | | |
| Individual/ group 2 | | | |
| Individual/ group 3 | | | |

*The following questions address opportunities and threats to the options identified before.*

In an organisation situations or developments can occur that hamper or, alternatively, facilitate a planned policy. In a university, for example the job opportunities in a specific field are an important determinant of the number of students starting their studies in this field.
Which three situations or developments are the most influential for your actions with regard to [subject]?

(If you describe a development over time, again please indicate the expected direction of the development. For example, refer to ‘decrease in job opportunities’ instead of ‘job opportunities’.)

Situation/ development 1.

Situation/ development 2.

Situation/ development 3.

Please indicate your estimation of the likelihood that these situations or developments will manifest themselves in [time period of concern].

| | very likely | likely | neutral | unlikely | very unlikely |
|---|---|---|---|---|---|
| Situation/ development 1 | o | o | o | o | o |
| Situation/ development 2 | o | o | o | o | o |
| Situation/ development 3 | o | o | o | o | o |

Please indicate whether these situations or developments present an opportunity or threat for the options identified before (see page 4). Please give your answer again on a scale of –5 to +5, indicating:

-5 = makes the implementation of this option very difficult;
0 = has no influence on the implementation of this option;
+5 = makes the implementation of this option very easy.

For example, if you fill out -5 after situation/ development 1 in the first column (see the following table), you indicate that you think situation/ development 1 makes the implementation of option 1 very difficult.

| | Option 1 | Option 2 | Option 3 |
|---|---|---|---|
| Situation/ development 1 | | | |
| Situation/ development 2 | | | |
| Situation/ development 3 | | | |

Please indicate the importance of [subject] for your organisation.

| | very important | important | neutral | unimportant | very unimportant |
|---|---|---|---|---|---|
| The [subject] is for my organisation | o | o | o | o | o |

Please indicate the importance of [subject] to you personally.

| | very important | important | neutral | unimportant | very unimportant |
|---|---|---|---|---|---|
| The [subject] is to me personally | o | o | o | o | o |

In the modelling sessions we discussed a number of options for [subject]. The questions in the following section address the extent to which the options have been discussed on a number of important aspects.

| | strongly agree | agree | agree/ disagree | disagree | strongly disagree |
|---|---|---|---|---|---|
| 1. In the meetings all relevant options were addressed. | o | o | o | o | o |
| 2. In the meetings all relevant goals were addressed. | o | o | o | o | o |
| 3. In the meetings all relevant values were addressed. | o | o | o | o | o |
| 4. In the meetings all relevant costs were addressed. | o | o | o | o | o |
| 5. In the meetings all relevant risks were addressed. | o | o | o | o | o |
| 6. In the meetings all important information for weighing alternative options was addressed. | o | o | o | o | o |
| 7. The recommendations were reached on the basis of an integration of all relevant information. | o | o | o | o | o |
| 8. The recommendations were reached on the basis of an evaluation of all positive and negative outcomes. | o | o | o | o | o |
| 9. In formulating options all relevant conditions were taken into account. | o | o | o | o | o |
| 10. In formulating options all relevant contingencies were taken into account. | o | o | o | o | o |

The meetings consisted of several elements which may have contributed in different ways to the overall effect of the meetings. In the following questions you are asked to specify how much each element contributed to the overall effect. You can do this by scoring each element on a scale of -5 to +5, in which:

-5 = was of no use whatsoever, obstructed the sessions;
0 = did not obstruct, but was of no use either;
+5 = contributed very much.

| | score -5 to +5 |
|---|---|
| The fact that the diagrams were projected/recorded in a way that was visible to everybody. | |
| The fact that an outsider was accompanying as a 'group facilitator'. | |
| The opportunity for open and extensive discussion. | |
| The use of causal diagrams. | |
| Parameter estimation. | |
| Analysis of the formalised model. | |

| | |
|---|---|
| Data analysis. | |
| Analysis of model output. | |
| Others, … | |

The following questions address different aspects of the modelling sessions. Please answer these questions by checking the response of your choice.
The modelling sessions were characterised by:

| | strongly agree | agree | neutral | disagree | strongly disagree |
|---|---|---|---|---|---|
| 1. Open communication. | o | o | o | o | o |
| 2. Clear and understandable communication. | o | o | o | o | o |
| 3. The fact that everybody had the opportunity to bring their point of view to the fore. | o | o | o | o | o |
| 4. Ample opportunity to discuss issues about which there was disagreement. | o | o | o | o | o |
| 5. A businesslike and focussed approach. | o | o | o | o | o |
| 6. Attention for each others' ideas and viewpoints. | o | o | o | o | o |
| 7. The fact that some persons dominated the discussions. | o | o | o | o | o |
| 8. Time pressure. | o | o | o | o | o |

*The following two questions address the complete modelling project.*

| | strongly agree | agree | neutral | disagree | strongly disagree |
|---|---|---|---|---|---|
| 9. Using modelling in approaching the problem is efficient. | o | o | o | o | o |
| 10. All in all I think these meetings were successful. | o | o | o | o | o |

If you compare these meetings using different techniques (such as causal diagrams), with *normal meetings or conferences* in which you discuss *similar problems*, would you say these meetings:

| | strongly agree | agree | neutral | disagree | strongly disagree |
|---|---|---|---|---|---|
| 1. give *more* insight compared to normal meetings? | o | o | o | o | o |
| 2. give insight compared to normal meetings *more quickly*? | o | o | o | o | o |
| 3. result in a *better* communication between participants? | o | o | o | o | o |
| 4. give rise to a shared vision between participants *more quickly*? | o | o | o | o | o |
| 5. give rise to a *better* shared vision between participants? | o | o | o | o | o |
| 6. give rise to commitment of participants *more quickly*? | o | o | o | o | o |
| 7. give rise to *more* commitment of participants? | o | o | o | o | o |

What specific suggestions would you make if meetings like these were to be organised or held again?

a. ______________________________

______________________________

______________________________

b. ______________________________

______________________________

______________________________

c. ______________________________

______________________________

______________________________

*End of the questionnaire. Thank you again for your cooperation.*

*Appendix D.*

# General description of the data

In this section the data gathered in this study are described with regard to eight characteristics:

1. assumptions regression analysis;
2. context factors per case;
3. measurement of beliefs;
4. description of outcome variables;
5. relations between outcome variables;
6. interaction effects between pretest and treatment;
7. relation of process elements and outcome variables;
8. relation of context, mechanism and outcome variables.

## 1. Assumptions regression analysis

In this study regression analysis is used to estimate changes in outcome variables (intention, attitude, norm, control and beliefs). In order to assess whether the data confirm to the assumptions underlying regression analysis, the data were tested for the following four aspects (Hair et al., 1998: 172):

- linearity;
- constant variance of error terms;
- independence of error terms;
- normality of error term distribution.

The dependent variables in this study are intention, attitude, norm, control and beliefs. In the analyses two sets of independent variables are used. In the analysis of hypotheses, each of the dependents is regressed on pretest scores and treatment (positive versus negative arguments). Next, dependent variables are regressed on pretest scores, treatment and mechanism scores. Mechanism scores include process aspects (argument quality and process quality) as well as element scores (e.g. evaluation of projection of diagrams or the facilitator). In order not to complicate the discussion in this section, only the pretest scores and treatment will be involved in the analysis.

*Linearity*

The first assumption underlying regression analysis mentioned by Hair et al. (1998: 173) is the linearity of the relationship between dependent and independent variables. A measure for linearity is the residual (difference between observed and predicted values for the dependent). If the relationship between dependent and independent variables is linear, residuals will be normally distributed for independent variables or for predicted values of the dependent variable. Inspection of plots of residuals versus predicted values of the dependent variables, indicates no consistent curvilinear patterns for any of the dependent variables. Section 6 of this appendix reports on a regression of posttest scores on pretest, treatment and the interaction of pretest and treatment. The interaction term has no significant effect on posttest scores, which confirms the conclusion that the relation between independent and dependent variables is approximately linear.

*Variance of the error terms*

The second assumption of regression analysis is that the variance of the error term is constant for values of the predicted dependent variables. This can again be tested by visual inspection of plots of residuals versus predicted values of the dependent variables. Inspection of these plots shows an approximately even dispersion of residuals across values of the predicted values of the dependent variables.

*Independence of the error terms*

The third assumption underlying regression analysis described by Hair et al. (1998), is the independence of predicted values from any other predictions. In this study, variables that could have an effect are time, interaction of pretest and treatment scores, correlated error on the individual level as well as various mechanism variables. The effect of time is controlled by including pretest scores in the regression analysis. The independence of error related to pretest score and treatment is tested in section 4 of this appendix. For outcome variables, errorterms might be correlated as several measures are obtained from a single individual, e.g. one individual is asked to provide two to four attitude scores. The effect of correlated error at the level of the individual is tested in section 7 of this appendix and found to be small. (The case level can be expected to introduce a correlated error in the same fashion. However, the effect of the case level is included in regression analyses, see section 8.) The effect of mechanism variables is explicitly tested in sections 7.5 and 7.6. In conclusion, I assume that error terms are independent.

*Normality of error term distribution*

The final assumption underlying regression analysis is that independent and dependent variables are normally distributed. In this study this assumption is clearly violated in the case of intentions, attitude, norm and control. With regard to these variables, scores above neutral are far more common than scores below neutral. Scores on beliefs follow an approximately normal distribution. Although part of the data does not follow a normal distribution, there are two arguments that support the use of regression analysis. First, this is a common assumption violation (Hair et al., 1998: 175) and regression analysis is relatively robust for transgressions of normality. Second, the data were analysed assuming that scores are not continuous but categorical, using multilevel analysis. This analysis did not lead to changes in conclusions.

In conclusion, the data follow the assumptions underlying regression analysis with the exception of normality of distribution. Two arguments were presented for using regression although data are not normally distributed.

## 2. Context factors per case

In this section the main contextual factors on the individual level are reported. Chapter six describes the contextual factors related to organisational characteristics and problem complexity for each case. In the following, data are reported on motivation to process information, extent to which participants can implement conclusions, age and years working with organisation. Section 5.4.6 described the role of motivation to process information and ability to implement conclusions. Both are expected to be high, which fosters processing of information during the modelling sessions. Age and years working with organisation are general background characteristics; there are no specific prior expectations about the effect of these variables.

For each variable, first the data for each case are reported. In order not to provide too many details, the analysis of the effect on posttest scores is limited to the three main outcome variables: attitude towards behaviour, subjective norm and perceived behavioural control. For each of these three variables, posttest scores will be regressed on pretest scores and contextual variables.

*Motivation to process information*

Motivation to process information is measured by two items in pretest and posttest (see section 5.4.6) on importance to the organisation. In addition, the importance of the problem to the individual respondent was assessed. As can be seen from the table below, problem importance scores from 3.90 to 5.00.

| | *Pretest importance organisation* | | *Pretest importance individual* | | *Posttest importance organisation* | | *Posttest importance individual* | |
|---|---|---|---|---|---|---|---|---|
| | Mean (SD) | n | Mean (SD) | n | Mean (SD) | n | Mean (SD) | n |
| Case 1 | 4.20 (.79) | 10 | 4.20 (.63) | 10 | 4.60 (.52) | 10 | 3.90 (.74) | 10 |
| Case 2 | 4.00 (.00) | 6 | 4.33 (.52) | 6 | 4.33 (.52) | 6 | 4.17 (.75) | 6 |
| Case 3 | 4.71 (.49) | 7 | 4.00 (1.15) | 7 | - | 0 | - | 0 |
| Case 4 | 4.22 (.19) | 3 | - | 0 | 5.00 (.00) | 2 | 4.50 (.71) | 2 |
| Case 5 | 4.25 (.17) | 4 | - | 0 | 4.33 (.47) | 2 | - | 0 |

*Table 1 Appendix D: problem importance*

Although in section 5.4.6 it was assumed that individual and organisational problem importance were not necessarily correlated, the data indicate that the problems modelled in this research score high on both dimensions. The expectation that the intervention (by structuring the problem) results in a different perception of problem importance is not corroborated either. There are no large changes in problem importance from pretest to posttest. Case 3 and 4 score higher than case 1, 2 and 5 on importance to the organisation. As described in section 5.5.5, motivation to process information was measured on the basis of individual and organisational importance (in pretest and posttest). The mean score of motivation to process information over all cases is 4.40 (sd .52, minimum 3.00, maximum 5.00, n=33).

*Ability to implement conclusions*

In the following results are reported on the extent to which participants can implement conclusions. Since this variable has dichotomous scores, a count of values and the proportion of implementable options is shown in the following table.

| | *Count* | | *Proportion implementable* |
|---|---|---|---|
| | *not implementable* | *implementable* | |
| Case 1 | 8 | 19 | .70 |
| Case 2 | 5 | 19 | .79 |
| Case 3 | 3 | 11 | .79 |
| Case 4 | 3 | 6 | .67 |
| Case 5 | 4 | 8 | .67 |

*Table 2 Appendix D: extent to which options can be implemented*

As can be seen from the table, the proportion of implementable options ranges from 67 to 79% per case. This is confirmed by the interview data. In a limited number of interviews, participants were asked to which degree they could set priorities in the problem modelled. All answers indicate a considerable margin for deciding which action to implement. Again, the comparable score per case does not lead us to expect an effect on mechanism and outcome variables. In conclusion, the extent to which conclusions can be implemented is high for each case (around 70%).

*Age and years with organisation*

In the following results with regard to age and years with the organisation are reported. The theory surveyed in chapters two and four does not specify any relations between these variables and mechanism or outcome variables.

| | *Age* | | *Years with organisation* | |
|---|---|---|---|---|
| | Mean (SD) | n | Mean (SD) | n |
| Case 1 | 50 (5.85) | 10 | 14 (10.07) | 10 |
| Case 2 | - | 0 | 5 (1.05) | 6 |
| Case 3 | 36 (14.20) | 4 | 6 (0) | 1 |
| Case 4 | 59 (4.58) | 3 | 12 (8.00) | 3 |
| Case 5 | 50 (9.46) | 4 | - | 0 |

*Table 3 Appendix D: age and years with organisation*

As can be seen from the table, respondents in case 4 are relatively older than respondents in case 1, 3 and 5. Compared to case 1 and 4, participants in case 2 and 3 on average have spent less years working with the organisation. Age and years with organisation were not entered in the regression of process and outcome variables reported in section 7.5, because the number of respondents which did not answer either or both of these questions was too large. As can be seen from table 7, listwise deletion of cases would lead to a large reduction in the number of measurements. Instead, the effect of both variables will be tested by a regression of process quality on age and a regression of process quality on years with organisation. Similarly, argument quality will be regressed on age and process quality seperately. As the following table indicates, there is only one significant effect: years with organisation has a positive effect on argument quality. On the basis of the theories used to formulate hypotheses for this study, this result cannot easily be interpreted.

| | Process quality | | | Argument quality | | |
|---|---|---|---|---|---|---|
| | B | t | significance | B | t | significance |
| age | -.01 | -1.32 | .20 | .02 | 2.00 | .06 |
| years with organisation | .01 | 1.29 | .21 | .03 | 2.84 | .01 |

*Table 4 Appendix D: simple regression of mechanism variables on age and years with organisation*

Next the effect of age and years with organisation on outcome variables is assessed, by regressing evaluations on both variables seperately. Again we expect no significant effects. However, the following table shows that age does have a significant effect on posttest attitude. Again, this result cannot easily be interpreted. Since age doe not have a significant effect on both other evaluations (subjective norm and perceived control), this will be considered a spurious relationship.

| | Attitude toward behaviour | | | Subjective norm | | | Perceived behavioural control | | |
|---|---|---|---|---|---|---|---|---|---|
| | B | t | sign | B | t | sign | B | t | sign |
| pretest eval | .63 | 5.55 | .00 | .66 | 5.81 | .00 | .29 | 1.95 | .06 |
| age | -.02 | -2.85 | .01 | .01 | -.47 | .64 | -.01 | -.49 | .62 |
| pretest eval | .75 | 6.32 | .00 | .75 | 8.07 | .00 | .45 | 3.67 | .00 |
| years w/o | .00 | .241 | .81 | .01 | .87 | .39 | .02 | 1.43 | .16 |

*Table 5 Appendix D: simple regression of main outcome variables on age and years with organisation*

In conclusion, age and years with organisation have a specifying effect on mechanism or outcome in two instances. Because these represent only a minority of possible effects and cannot be related to any theoretical propositions, they will not be included in the analysis of hypotheses.

*Relation between context variables*

In order to assess relations between context variables, the covariance of motivation, ability to implement conclusions, age and year with organisation will be estimated. The following table shows the result of a covariance analysis.

| | *years with organisation* | *ability to implement conclusions* | *motivation* |
|---|---|---|---|
| age | .05 (n=38) | .28** (n=56) | .20 (n=56) |
| years with organisation | | .10 (n=62) | .05 (n=73) |
| ability to implement conclusions | | | .09 (n=86) |

*Table 6 Appendix D: covariance of age, years with organisation, ability to implement conclusions and motivation, cells contain Pearson correlation coefficients and n, ** significant at the .05 level*

As can be seen from the table, the only significant correlation is between age and ability to implement conclusions. Since this does not directly impact any of the relations proposed by the theories considered in chapters two and four, this relation will not be taken into consideration in the further analysis of results.

### 3. Measurement of beliefs

In this section the difference between self-generated beliefs and beliefs identified by the researcher is described. One approach to identifying differences is to describe mean scores and standard deviations for both types of beliefs. However, since each of the categories is measured in different cases and also use a different number of beliefs, it is difficult to determine whether differences found are due to the source (respondent or researcher) or to other factors. In case 1 and 3, respondents formulate beliefs. In case 1 two beliefs are identified for each category (outcome, normative and control). In case 3, respondents formulate three beliefs for each category. In case 2, case 4 and case 5 beliefs are specified by the researcher. In case 2, respondents are asked to answer questions on seven behavioural beliefs, six normative beliefs and three control beliefs. In both case 4 and 5, the researcher specified six beliefs for each category. It is clear that the number of beliefs specified by the researcher is on average higher than the number of self-generated beliefs.

Differences between beliefs will therefore only be tested by looking the relation of both types of beliefs with semantic differential measurements. The following table shows correlations between belief-based and semantic differential measurements for both types of beliefs.

| | *Pretest* | | *Posttest* | |
|---|---|---|---|---|
| | Self-generated | Researcher | Self-generated | Researcher |
| Behavioural beliefs | -.04 | .01 | .08 | .02 |
| Normative beliefs | -.18 | .58** | .13 | .57** |
| Control beliefs | -.18 | -.25 | .23 | .24 |

*Table 7 Appendix D: pearson correlation coefficients between belief-based and semantic differential measurements, ** indicates significant correlation at the .01 level*

As the table shows, correlations for beliefs generated by the researcher are on average higher. This is contrary to the expectations found in the literature (Eagly and Chaiken, 1993: 234). However, for both types of beliefs correlations increase from pretest to posttest. As indicated above, the observed differences might be due to the higher number of beliefs employed in the researcher-based measurements. In section 7.3.2, the relation between beliefs and evaluations is explored further.

## 4. Description of outcome variables

*Beliefs*

This section focuses on changes in beliefs from pretest to posttest. The following table shows results with regard to beliefs that received positive information and beliefs that received negative information. Please note that beliefs are calculated by combining belief strength (scale –5 to +5) and evaluation of the outcome (scale 1 to 5) as described in section 5.4.3.

| | *pretest* | | | *posttest* | | |
|---|---|---|---|---|---|---|
| | mean | sd | n | mean | sd | n |
| positive behavioural beliefs | 6.41 | 8.21 | 66 | 8.79 | 8.41 | 61 |
| negative behavioural beliefs | 1.31 | 6.57 | 10 | 2.16 | 6.48 | 9 |
| positive normative beliefs | 7.15 | 8.15 | 66 | 8.17 | 8.52 | 62 |
| negative normative beliefs | -1.32 | 9.49 | 10 | .96 | 4.23 | 9 |
| positive control beliefs | 4.61 | 8.34 | 66 | 4.22 | 8.44 | 62 |
| negative control beliefs | .93 | 6.80 | 9 | -4.44 | 10.97 | 9 |

*Table 8 Appendix D: Mean scores for beliefs receiving positive arguments and negative arguments on pretest and posttest*

As the table indicates, the number of options receiving positive arguments is much higher than the number of options receiving negative arguments. The table shows that if the two categories of beliefs are separated, the mean score on behavioural and normative beliefs receiving positive arguments tends to increase. Contrary to expectations, the mean score on behavioural and normative beliefs receiving negative information also increases from pretest to posttest. Another unexpected result is that the score on control beliefs that receive positive information tends to become lower. Control beliefs that receive negative information change in the expected direction and score lower on the posttest. In addition to mean scores for the overall group, individual changes from pretest to posttest can be looked at as well. These changes are estimated by subtracting the pretest score of a particular option from the posttest score of the same option. The following table shows individual changes in beliefs.

| | decrease | unchanged | increase | n |
|---|---|---|---|---|
| behavioural beliefs | 27.1% | 8.6% | 64.3% | 70 |
| normative beliefs | 45.1% | 7.0% | 47.9% | 71 |
| control beliefs | 55.7% | 7.1% | 37.2% | 70 |

*Table 9* *Appendix D: Individual changes in belief scores from pretest to posttest, n is number of paired measurements (pretest and posttest completed)*

Note that in table 9, and in the following tables on individual changes, only those options are included for which direction of persuasion could be estimated. Options that are scored in category 11 are not included in the tables.

With regard to normative beliefs, additional information was obtained in the posttest questionnaire and the interview. In the posttest respondents are asked who they would ask for information about the problem modelled in the sessions (cf. Felling, 1974). The expectation is that answers indicate important referents for the participants, which form the basis for normative beliefs. The answers generally include a number of persons who are not present during the sessions. On average about 40% of the persons mentioned in the interviews are participants in the sessions. In the interview subjects are also asked if the group of participants in the sessions included all stakeholders and covered all fields of expertise on the problem. The answers generally indicate that all relevant stakeholders and fields of expertise are represented. About half of the subjects indicate that no groups were missed, while the other half indicate that only one particular group was missing. Frequently this group was considered by the gatekeeper while planning the session, but explicitly excluded from participating. An example of the latter is the group of young inhabitants in the case on public safety, as they were considered one of the

‘problematic groups’ and if participating would probably make for a very defensive discussion.
The answers to the questions on information sources versus presence of all stakeholders appear to be different: not everyone who is considered an information source is present in the session, while on the other hand no stakeholders are missed. The difference in answers might be due to the fact that stakeholders or fields of expertise can be taken to refer to groups, while the question on information sources clearly refers to individual persons. If stakeholders or interest areas are represented by a different person than the one listed as an information source, the concepts are not similar. In that case the individual that comes to mind as an information source was not participating in the sessions in person, but someone from his or her department or field of expertise was. However, to a large extent the answers to both questions point in the same direction: respondents feel that the participant group contained a number of important referents. This issue will be considered again in discussing results for hypothesis five on normative beliefs.

*Evaluations*
The following table shows pretest and posttest scores for evaluations receiving positive arguments and evaluations receiving negative arguments.

| | *pretest* | | | *posttest* | | |
|---|---|---|---|---|---|---|
| | mean | sd | n | mean | sd | n |
| positive attitude | 4.13 | .63 | 72 | 4.13 | .66 | 69 |
| negative attitude | 3.30 | 1.32 | 10 | 2.39 | .99 | 9 |
| positive norm | 3.67 | .86 | 72 | 3.84 | .87 | 69 |
| negative norm | 2.40 | 1.26 | 10 | 2.33 | 1.41 | 9 |
| positive control | 2.88 | .67 | 73 | 3.01 | .80 | 68 |
| negative control | 2.67 | .56 | 9 | 2.39 | .78 | 9 |

*Table 10 Appendix D: Mean scores for evaluations receiving positive arguments and negative arguments on pretest and posttest*

As can be seen from the table, the number of evaluations receiving negative arguments is again much smaller than those receiving positive arguments. Evaluations receiving positive arguments do not show large changes from pretest to posttest: attitude remains unchanged, subjective norm and perceived behavioural control show a small increase. Evaluations receiving negative arguments tend to decrease. The table also shows that the largest change from pretest to posttest is found for attitudes receiving negative arguments. The following table shows individual changes in evaluations.

| | decrease | unchanged | increase | n |
|---|---|---|---|---|
| attitude | 29.5% | 42.3% | 28.2% | 78 |
| norm | 19.2% | 50.0% | 30.8% | 78 |
| control | 28.6% | 31.2% | 40.2% | 77 |

*Table 11 Appendix D: Individual changes in evaluation scores from pretest to posttest, n is number of paired measurements (pretest and posttest completed)*

The proportion of evaluations that does not change from pretest to posttest is smaller than that of beliefs. As the table indicates, 31.2 to 50.0% of evaluations do not show changes from pretest to posttest, while for beliefs 7.0 to 8.6% remains unchanged.

*Intentions and behaviour*

This section addresses changes in intentions and actions from pretest to posttest. Please recall that for intentions the expected direction of change is determined by selecting the categories of change for which attitudes, norm and control change in a similar direction. For example if both attitudes, norm and control are expected to change in a negative direction, intention is expected to decrease as well. In this way the number of actions for which the change in intentions can be determined is smaller than for the other variables in the Ajzen model. As the following table shows, for 64 behavioural options the expected direction of change for intention can be assessed.

| | *pretest* | | | *posttest* | | |
|---|---|---|---|---|---|---|
| | mean | sd | n | mean | sd | n |
| positive intentions | 4.16 | .76 | 62 | 4.22 | .66 | 61 |
| negative intentions | 3.00 | 2.00 | 3 | 2.67 | 1.61 | 3 |

*Table 12 Appendix D: Mean scores for intentions receiving positive arguments and negative arguments on pretest and posttest*

Again the table reports mean scores for the overall group. Changes in intention scores on the individual level are as follows: 27.4% shows a decrease from pretest to posttest, 48.4% remains unchanged and 24.2% shows an increase (the number of paired measurements is 62).

With regard to behaviour no quantitative assessments were obtained. Instead interviews with the gatekeepers were held several months after the modelling projects, in order to determine which kind of follow-up was given to the recommendations of the project. After describing outcome variables, the following section addresses into relations between outcomes.

## 5. Relations between outcome variables

This section focuses on the relations between outcomes: beliefs, evaluations, intentions and behaviour. The relations between variables in the Ajzen model are described by looking at measures employed in traditional attitude research (regression analysis) and a qualitative measure proposed by evaluation researchers (Pawson and Tilley, 1997). Van den Putte (1993) and Ajzen (1991) employ the following quantitative tests for the model's sufficiency:

- a regression of intention on attitude towards behaviour, subjective norm and perceived behavioural control;
- a regression of attitude, subjective norm and perceived control on beliefs.

In the following, quantitative measures are described first. Next I turn to the qualitative measure used in evaluation research.

*Regression of intention on attitude, norm and perceived control*

The first test of the relations in the Ajzen model applied to group model building interventions is the prediction of intention by attitude, subjective norm and perceived behavioural control. Attitude, subjective norm and perceived behavioural control were entered in the regression equation in that sequence. The following table shows regressions and correlations for the variables in the Ajzen theory in the pretest for all behavioural options.

| *Pretest* n=82 | Subjective norm | Perceived behavioural control | Intention | B | β | part. corr. | Sig($t$) |
|---|---|---|---|---|---|---|---|
| Attitude | $r$ = .47** | $r$ = .04 | $r$ = .60** | .50 | .39 | .45 | .00 |
| Subjective norm | | $r$ = .29** | $r$ = .64** | .42 | .44 | .47 | .00 |
| Perceived behavioural control | | | $r$ = .21* | .10 | .07 | .09 | .41 |

*Table 13 Appendix D: Pretest correlations of attitude, subjective norm, perceived behavioural control and intention, and multiple regression of intention on attitude, subjective norm and and perceived behavioural control, **indicates that the correlation is significant at the .01 level (one-tailed), *indicates that the correlation is significant at the .05 level (one-tailed)*

The table can be read as follows. The first row for example shows the correlation of attitude to subjective norm, perceived behavioural control and intention. The last four colums show the results of a regression of intention on attitude, norm and control. Attitude is a significant predictor of intention (B=.50, β=.39) and has a high partial correlation to intention (.45). From the table it can be concluded that attitude and subjective norm correlate highly with intention and with each other. Perceived control has a weak but significant correlation with subjective norm (at the .01 level) and intention (at the .05 level). In combination, the predictive power of attitude, subjective norm and perceived control is significant ($R^2$=.53). However, only attitude and subjective norm are significant independent predictors. Perceived control does not need to be included to explain pretest scores.

The following table shows regressions and correlations for the variables in the Ajzen theory in the posttest for all behavioural options.

| *Posttest* n=79 | Subjective norm | Perceived behavioural control | Intention | B | β | part. corr. | Sig($t$) |
|---|---|---|---|---|---|---|---|
| Attitude | $r$ = .63** | $r$ = .39** | $r$ = .78** | .59 | .50 | .58 | .00 |
| Subjective norm | | $r$ = .40** | $r$ = .74** | .39 | .39 | .48 | .00 |
| Perceived behavioural control | | | $r$ = .42** | .08 | .06 | .10 | .37 |

*Table 14 Appendix D: Posttest correlations of attitude, subjective norm, perceived behavioural control and intention, and multiple regression of intention on attitude, subjective norm and and perceived behavioural control, **indicates that the correlation is significant at the .01 level (one-tailed)*

A number of results are similar to the pretest. Attitude and subjective norm correlate highly with intention and with each other. Perceived control has a significant correlation with subjective norm and intention. Again, the predictive power of attitude, subjective norm and perceived control in combination is significant ($R^2$=.71). However, only attitude and subjective norm are significant independent predictors. Similar to the pretest, perceived control does not need to be included to explain posttest scores. What is different from the pretest is that perceived control and attitude are significantly correlated. In addition, explained variance increased by 34% ($R^2$ changes from .53 to .71).

On the basis of both pretest and posttest scores, intention seems to be significantly predicted by attitude and subjective norm. Ajzen's addition of perceived behavioural control to the theory of reasoned action does not seem to be necessary to explain behavioural intentions related to group model building. From the prediction of intention by attitude, subjective norm and perceived behavioural control, we can conclude that the theory of planned behaviour offers a sufficient explanation of intentions in this domain but the inclusion of the variable perceived control is not necessary.

*Regression of attitude, norm and perceived control on beliefs*

The second test of the relation between outcome variables, is a regression of evaluations on corresponding beliefs. The following table shows correlations and regressions for the pretest.

| *Pretest* | Norm beliefs | Control beliefs | Attitude | Subjective norm | Perceived behavioural control | $R^2$ | β | Sig(*t*) | n |
|---|---|---|---|---|---|---|---|---|---|
| Behavioural beliefs | r =.58** | r = .31** | r = .11 | r = .28** | r = .17 | .01 | .11 | .31 | 80 |
| Normative beliefs | | r =.32** | r = .25* | r = .44** | r = -.00 | .19 | .44 | .00 | 80 |
| Control beliefs | | | r = .02 | r = .03 | r = -.24* | .06 | -.24 | .04 | 78 |

*Table 15 Appendix D: Pretest correlations of attitude, subjective norm and beliefs, and simple regression of evaluation on corresponding beliefs, *indicates that the correlation is significant at the .05 level (one-tailed), **indicates that the correlation is significant at the .01 level (one-tailed)*

The last four columns of the table show the result of a regression of each evaluation on its corresponding beliefs. The first row for example shows the regression of attitude on behavioural beliefs. As the table indicates, control, normative and behavioural beliefs are correlated and the relations between beliefs and corresponding evaluations are weak. Ajzen (1991: 195) points out that correlations between semantic differential measures (evaluations) and belief-based measures (beliefs) are usually of only moderate magnitude. Behavioural beliefs at best explain between 10 and 36% of the variance in attitudes. Subjective norm and perceived control follow the same pattern. In the pretest scores for this study only normative beliefs fall into this pattern ($R^2$=.19). Attitude has a higher correlation with normative beliefs than with behavioural beliefs, while control is negatively correlated with control beliefs[1].

The following table shows correlations and regressions for the posttest.

| *Posttest* | Norm beliefs | Control beliefs | Attitude | Subjective norm | Perceived behavioural control | $R^2$ | β | Sig(*t*) | n |
|---|---|---|---|---|---|---|---|---|---|
| Behavioural beliefs | *r* =.31** | *r* =.43** | *r* = .34** | *r* = .44** | *r* = .07 | .12 | .34 | .00 | 73 |
| Normative beliefs | | *r* =.28* | *r* = .41** | *r* = .50** | *r* = .14 | .25 | .50 | .00 | 75 |
| Control beliefs | | | *r* = .28** | *r* = .20* | *r* = .23* | .05 | .23 | .05 | 73 |

*Table 16 Appendix D: Posttest correlations of attitude, subjective norm and beliefs, and simple regression of evaluation on corresponding beliefs, *indicates that the correlation is significant at the .05 level (one-tailed), **indicates that the correlation is significant at the .01 level (one-tailed)*

Correlations between belief-based measures are lower in the posttest than in the pretest (with the exception of behavioural and control beliefs), while correlations of belief-based and semantic differential measurements grow stronger. With the exception of control, the variance explained by beliefs in semantic differential measurements falls within Ajzen's (1991) margin of 10 to 36%. The semantic differential measurements of attitude and norm correlate to all belief categories, while control only has a significant correlation with control beliefs.
After the measures for completeness of the Ajzen model used in traditional attitude research, I now turn to a more qualitative measure proposed by evaluation researchers.

[1] The literature on belief based measurements indicates that self-generated beliefs have a stronger correlation to semantic differential measurements than beliefs generated by the researcher (Eagly and

*A qualitative measure for completeness of the model*

An alternative measure of the relations specified by the Ajzen model is described by Pawson and Tilley (1997). They propose to confront respondents with the research model and ask for comments. In the interviews after the modelling sessions, the research model was shown to participants, who were then asked whether the variables in the model could explain their behaviour in the problem adressed in the sessions. In general, respondents in this study recognise the variables in the model and think each of these is important in deciding how to react to a problem. Some participants propose additions to the model, that in general boil down to the subjective nature of the Ajzen variables. Four additions are proposed in the interviews. First, some participants stress that the concepts in the model are subjective and their relative weight varies over situations. All variables are an individual's subjective estimations which may not always be realistic. Actual control might for example not resemble perceived control, as was also pointed out by Ajzen (1991). The relative weight of attitude, norm and control is different depending on the person or behaviour addressed.

Second, when thinking about action alternatives participants always consider the feasibility of an action. An important influence on feasibility is the anticipated reaction of other stakeholders which are necessary in implementing new options. At first sight this seems to be incorporated in the Ajzen model in the form of normative beliefs. However, since other stakeholders' reactions and counteractions to these reactions are anticipated, this also has elements that go beyond single actions and concern policy games played out over a longer time period. This might for example lead participants to choose an option less favourable in the short term, to gain credit with other stakeholders and gain more rewards on the long term. The Ajzen model only captures antecedents of a single action, and possible repercussions for subsequent behaviours can only be incorporated as either behavioural, normative or control beliefs.

Third, an individual does not consider all behaviours since his or her task in the organisation puts boundaries on the actions that can be implemented.

Fourth, action alternatives in a problem are only considered if a problem is sufficiently urgent with regard to other problems. This resembles the attention threshold mentioned by Mintzberg et al. (1976): a problem will only become the focus of attention and the subject of a decision process, if a certain threshold with regard to its urgency is exceeded. Interviewees also mention that if a problem is on the decision agenda in their own organisation, it is likely to become a topic for individual decision making as well.

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Chaiken, 1993: 234). Section 3 of appendix D shows correlations between beliefs and evaluations for both types of beliefs.

This concludes the discussion of relations between outcome variables. The following section addresses the degree to which error terms in pretest and treatment scores are independent.

## 6. Independence of error terms pretest and treatment

This section describes the degree to which error terms of pretest score and treatment are dependent. Independence of error terms is mainly important for hypotheses 4 to 10 on beliefs, evaluations and intentions. In order to assess differences between pretest and posttest scores for each of these variables, posttest scores will be regressed on pretest scores, treatment, case dummies, related variables in the Ajzen model, context and mechanism variables. As indicated in section 1 of this appendix, this assumes that error terms for pretest and treatment are independent. In order to test this assumption, the collinearity of pretest score and treatment using the full set of independent variables was tested. For example, posttest behavioural belief was regressed on pretest behavioural belief, treatment, case dummies, posttest normative belief, posttest control belief, implementation, motivation, process quality, argument quality, and the interaction of motivation, process quality and argument quality. In testing collinearity no correlated error on the level of the respondent was assumed. The tolerance of pretest and treatment is shown in the following table.

| | *Tolerance pretest* | *Tolerance treatment* | *n* |
|---|---|---|---|
| behavioural beliefs | .28 | .67 | 56 |
| normative beliefs | .36 | .67 | 56 |
| control beliefs | .44 | .48 | 56 |
| attitude towards behaviour | .63 | .55 | 56 |
| subjective norm | .37 | .53 | 56 |
| perceived behavioural control | .75 | .48 | 56 |
| intention | .52 | .47 | 48 |

*Table 17 Appendix D: tolerance of pretest and treatment for beliefs, evaluations and intentions*

As the table indicates, tolerance values range from .28 to .75. As these scores are above .25 which is suggested as a lower limit, error terms of pretest and treatment will be considered to be independent.

## 7. Relation between process elements and outcomes

In this section the effect of separate process elements, e.g. presence of the facilitator or model analysis are described. Process elements that are relevant to the quantitative modelling cases (parameter estimation, analysis of the model, analysis of data and simulation of the model) are only included in a subset of the modelling cases. Analysis of data and simulation were only included in case 4 and 5, while parameter estimation and model analysis were included in case 3. For all of these variables a regression model including pretest and treatment effects cannot be specified. Therefore these variables will not be included in the analysis. In the discussion of hypothesis 3 the overall results of these measurements are described. Process elements that were present in both qualitative and quantitative modelling cases are the following: projection of diagrams, presence of a facilitator, opportunity for open discussion and use of causal loop diagrams. In order to test the relation between process elements and outcome measures, outcomes were regressed on pretest scores, treatment (positive versus negative arguments) and the separate items on process elements. Results are reported for a free error at the level of the respondent and option.

| | $\beta_0$ | $\beta_1$ pretest | $\beta_2$ treatment | $\beta_3$ projection | $\beta_4$ facilitator | $\beta_5$ discussion |
|---|---|---|---|---|---|---|
| behavioural beliefs | -9.50 (3.38)** | .61 (.08)** | 1.04 (1.38) | .18 (.88) | 1.10 (.51)* | 1.64 (1.20) |
| normative beliefs | -7.56 (5.40) | .53 (.10)** | .18 (1.72) | 1.06 (1.49) | .71 (.88) | 1.42 (1.72) |
| control beliefs | -5.86 (3.97) | .60 (.10)** | 5.70 (2.44)* | .06 (1.00) | -.35 (.57) | -.29 (1.17) |
| attitude | .72 (.40) | .49 (.10)** | .99 (.25)** | -.03 (.08) | .12 (.05)* | -.05 (.10) |
| subjective norm | 1.05 (.57) | .51 (.11)** | .40 (.35) | .02 (.13) | .10 (.08) | -.05 (.15) |
| perceived behavioural control | 1.31 (.71)** | .32 (.15)* | .80 (.31)** | -.12 (.14) | .03 (.08) | -.02 (.17) |

| | $\beta_6$ diagrams | $u_{oj}$ | $e_{0ij}$ | fit | n |
|---|---|---|---|---|---|
| behavioural beliefs | .43 (.89) | 9.34 (3.94)** | 9.12 (2.18)** | 321.931 | 58 |
| normative beliefs | -.45 (1.03) | 34.41 (11.53) | 12.88 (3.09)** | 366.432 | 59 |
| control beliefs | 1.19 (.73) | -5.10 ( 5.74) | 30.63 (7.18)** | 383.91 | 60 |
| attitude | .07 (.06) | .00 (.00) | .32 (.06)** | 110.073 | 65 |
| subjective norm | .05 (.09) | .07 (.09) | .58 (.13)** | 155.722 | 65 |
| perceived behavioural control | .11 (.10) | .21 (.11) | .41 (.09)** | 144.780 | 64 |

*Table 18 Appendix D: Regression of outcome scores on process elements (cells contain B coefficients and standard error), * significant at the .05 level, ** significant at the .01 level*

Parameters are as follows (e.g. for attitude measurements):

$$\text{posttest attitude}_{ij} = \beta_{0ij}\,\text{constant} + \beta_1\,\text{pretest attitude}_{ij} + \beta_2\,\text{treatment}_{ij} + \beta_3\,\text{projection diagrams}_j + \beta_4\,\text{facilitator}_j + \beta_5\,\text{open discussion}_j + \beta_6\,\text{causal loop diagrams}_j$$

$$\beta_{0ij} = \beta_0 + u_{0j} + e_{0ij}$$

Where i is behavioural option and j is respondent.

The table above also depicts the model fit or likelihood statistic. The statistic in itself is not a measure of the goodness of fit of a model as for example explained variance. The difference in the likelihood statistic for two models, the deviance, can be used as a significance test for comparing the models (Rasbash et al., 2000) and is used in analysis of outcome variables in the following sections[2].

As can be seen from the table, the score on presence of facilitator is a significant predictor at the .05 level of attitude and behavioural beliefs. Other process elements do not significantly predict outcome scores.

## 8. Relation between context, mechanism and outcome variables

In this section the results of a multiple regression analysis of outcome variables is reported. Outcome variables are regressed on correlated error on the level of the individual, pretest scores, case effects, related outcome variables, context and mechanism variables. These results are mainly important with regard to hypotheses 4 to 11, which are discussed in section 7.5.

| Posttest | $\beta_0$ | $\beta_1$ Pretest | $\beta_2$ Treatment | $\beta_3$ case 1 | $\beta_4$ case 2 | $\beta_5$ case 3 | $\beta_6$ case 4 |
|---|---|---|---|---|---|---|---|
| behavioural beliefs | -.22 (.28) | .28 (.12) | -.06 (.20) | .80 (.28) | -.69 (.47) | .98 (.43) | -.73 (.46) |
| normative beliefs | -.06 (.52) | .46 (.13) | .12 (.21) | -.19 (.55) | -.83 (.77) | .25 (.82) | -.55 (.90) |
| control beliefs | -.39 (.50) | .80 (.13) | .54 (.36) | -.02 (.34) | -.24 (.55) | -.02 (.51) | -1.16 (.48) |

[2] This procedure can be used where one model contains the other in that it fits extra parameters and thus will have a smaller value of the likelihood statistic: the difference is that of the second model minus the first model value with degrees of freedom equal to the difference in the number of parameters fitted in each model. The deviance follows a Chi squared distribution with degrees of freedom equal to the difference in the number of parameters fitted in each model.

| Posttest | $\beta_7$ Behavioural beliefs | $\beta_8$ Norm beliefs | $\beta_9$ Control beliefs | $\beta_{10}$ Implementation | $\beta_{11}$ Motivation |
|---|---|---|---|---|---|
| behavioural beliefs | | -.10 (.09) | .10 (.08) | .05 (.15) | .18 (.32) |
| normative beliefs | -.19 (.16) | | -.21 (.09) | .31 (.17) | .54 (.52) |
| control beliefs | -.03 (.18) | -.15 (.11) | | .07 (.21) | -.37 (.30) |

| Posttest | $\beta_{12}$ Process | $\beta_{13}$ Arguments | $\beta_{14}$ Process interaction | $u_{oj}$ | $e_{0ij}$ | fit | n |
|---|---|---|---|---|---|---|---|
| behavioural beliefs | .38 (.38) | .64 (.53) | -.74 (.71) | .08 (.04) | .13 (.03) | 66.14 | 57 |
| normative beliefs | 1.21 (.67) | 1.22 (.86) | -1.65 (1.16) | .44 (.15) | .13 (.03) | 97.46 | 57 |
| control beliefs | -.42 (.40) | -.72 (.50) | .76 (.67) | .00 (.00) | .38 (.07) | 106.89 | 57 |

*Table 19 Appendix D Multiple regression of posttest beliefs on correlated error, pretest beliefs, treatment, case effects, related outcome variables, context and mechanism variables (cells contain beta coefficients and standard error)*

| Posttest | $\beta_0$ | $\beta_1$ Pretest | $\beta_2$ Treatment | $\beta_3$ case 1 | $\beta_4$ case 2 | $\beta_5$ case 3 | $\beta_6$ case 4 |
|---|---|---|---|---|---|---|---|
| attitude | -1.22 (.31) | .30 (.10) | .99 (.33) | .45 (.34) | .34 (.46) | .59 (.49) | -.62 (.46) |
| subjective norm | .33 (.39) | .36 (.13) | .62 (.33) | -.67 (.39) | -1.05 (.47) | -1.02 (.53) | -.74 (.54) |
| perceived control | .79 (.70) | .06 (.13) | .40 (.47) | -1.15 (.45) | -1.30 (.73) | -1.61 (.69) | -.44 (.74) |

| Posttest | $\beta_7$ Beliefs | $\beta_8$ Attitude | $\beta_9$ Subjective norm | $\beta_{10}$ Perceived control | $\beta_{11}$ Implementation |
|---|---|---|---|---|---|
| attitude | -.14 (.16) | | .27 (.11) | .15 (.09) | .02 (.21) |
| subjective norm | .26 (.13) | .25 (.13) | | .05 (.10) | -.20 (.21) |
| perceived control | -.07 (.14) | .41 (.17) | -.04 (.16) | | -.14 (.28) |

| Posttest | $\beta_{12}$ Motivation | $\beta_{13}$ Process | $\beta_{14}$ Arguments | $\beta_{15}$ Process interaction | $u_{oj}$ | $e_{0ij}$ | fit | n |
|---|---|---|---|---|---|---|---|---|
| attitude | .43 (.28) | .31 (.37) | .37 (.47) | -.69 (.63) | .00 (.00) | .33 (.06) | 96.74 | 56 |
| subjective norm | .06 (.36) | .39 (.47) | .29 (.60) | -.52 (.81) | .07 (.06) | .30 (.07) | 102.02 | 56 |
| perceived control | -.44 (.46) | -.42 (.58) | -.72 (.76) | .86 (1.02) | .08 (.12) | .62 (.15) | 138.75 | 56 |

*Table 20 Appendix D Multiple regression of posttest evaluations on correlated error, pretest evaluations, treatment, case effects, related outcome variables, context and mechanism variables (cells contain beta coefficients and standard error)*

| Posttest | $\beta_0$ | $\beta_1$ Pretest | $\beta_2$ Treatment | $\beta_3$ case 1 | $\beta_4$ case 2 | $\beta_5$ case 3 | $\beta_6$ case 4 |
|---|---|---|---|---|---|---|---|
| intention | -.89 (6.77) | .33 (.12) | .80 (.54) | -.12 (.31) | -.32 (.44) | -.66 (.46) | -.83 (.54) |

| Posttest | $\beta_7$ Attitude | $\beta_8$ Subjective norm | $\beta_9$ Perceived control | $\beta_{10}$ Implementation |
|---|---|---|---|---|
| intention | .19 (.19) | .13 (.14) | -.01 (.13) | -.01 (.22) |

| Posttest | $\beta_{11}$ Motivation | $\beta_{12}$ Process | $\beta_{13}$ Arguments | $\beta_{14}$ Process interaction | $u_{oj}$ | $e_{0ij}$ | fit | n |
|---|---|---|---|---|---|---|---|---|
| intention | .52 (.75) | .12 (.87) | -.02 (1.03 ) | -.01 (.06) | .00 (.00) | .27 (.05) | 72.39 | 48 |

*Table 21* *Appendix D Multiple regression of posttest intention on correlated error, pretest intention, treatment, case effects, attitude, subjective norm, perceived behavioural control, context and mechanism variables (cells contain beta coefficients and standard error)*

*Appendix E*

# Data matrix

Variable codes in the datamatrix below correspond to the variables reported in appendix B, with the exception of OptiNo, RespNo, CaseNo and Option. OptiNo, RespNo and CaseNo indicate the behavioural option, respondent and case respectively. The variable 'Option' is a short summary of the content of the behavioural option. Variables which are measured at two points in time are indicated with Pr (pretest) and Po (posttest).

| OptiNo | RespNo | CaseNo | ImpoPr | ImpiPr | ImpoPr | ImpiPo | Implem | Ybirth | Yorg | Option |
|---|---|---|---|---|---|---|---|---|---|---|
| 10201 | 102 | 1 | 5 | 5 | 5 | 5 | 0 | 1946 | 1992 | timely intervention |
| 10202 | 102 | 1 | 5 | 5 | 5 | 5 | 0 | 1946 | 1992 | focus on inhabitants |
| 10203 | 102 | 1 | 5 | 5 | 5 | 5 | 1 | 1946 | 1992 | improve public space |
| 10301 | 103 | 1 | 4 | 4 | 5 | 4 | 1 | 1956 | 1975 | focus on inhabitants |
| 10302 | 103 | 1 | 4 | 4 | 5 | 4 | 1 | 1956 | 1975 | take care of pupils leaving school |
| 10303 | 103 | 1 | 4 | 4 | 5 | 4 | 1 | 1956 | 1975 | timely intervention |
| 10401 | 104 | 1 | 5 | 5 | 5 | 4 | 1 | 1944 | 1998 | take care of pupils leaving school |
| 10402 | 104 | 1 | 5 | 5 | 5 | 4 | 1 | 1944 | 1998 | take care of youths in disctrict |
| 10403 | 104 | 1 | 5 | 5 | 5 | 4 | 0 | 1944 | 1998 | improve cooperation agencies |
| 10501 | 105 | 1 | 4 | 4 | 5 | 4 | 1 | 1948 | 1973 | education for youths aged 4-12 |
| 10502 | 105 | 1 | 4 | 4 | 5 | 4 | 1 | 1948 | 1973 | form an open district school |
| 10503 | 105 | 1 | 4 | 4 | 5 | 4 | 0 | 1948 | 1973 | involve parents |
| 10701 | 107 | 1 | 4 | 4 | 4 | 4 | 1 | 1951 | 1982 | take care of pupils leaving school |
| 10702 | 107 | 1 | 4 | 4 | 4 | 4 | 0 | 1951 | 1982 | create home team aged 25-30 years |
| 10703 | 107 | 1 | 4 | 4 | 4 | 4 | 0 | 1951 | 1982 | foster social coherence |
| 10801 | 108 | 1 | 3 | 4 | 4 | 3 | 1 | 1954 | 1981 | take care of pupils leaving school |
| 10802 | 108 | 1 | 3 | 4 | 4 | 3 | 0 | 1954 | 1981 | create home team aged 25-30 years |
| 10803 | 108 | 1 | 3 | 4 | 4 | 3 | 0 | 1954 | 1981 | foster social coherence |
| 10901 | 109 | 1 | 5 | 3 | 5 | 3 | 1 | 1951 | 1982 | improve cooperation agencies |
| 10902 | 109 | 1 | 5 | 3 | 5 | 3 | 1 | 1951 | 1982 | timely intervention |
| 10903 | 109 | 1 | 5 | 3 | 5 | 3 | 1 | 1951 | 1982 | stricter collecting policy |
| 11101 | 111 | 1 | 5 | 4 | 5 | 3 | 1 | 1959 | 1997 | improve housing |
| 11102 | 111 | 1 | 5 | 4 | 5 | 3 | 1 | 1959 | 1997 | focus on inhabitants |
| 11103 | 111 | 1 | 5 | 4 | 5 | 3 | 1 | 1959 | 1997 | improve cooperation agencies |
| 11301 | 113 | 1 | 4 | 4 | 4 | 5 | 1 | 1963 | 1997 | more contact inhabitants - agencies |
| 11302 | 113 | 1 | 4 | 4 | 4 | 5 | 1 | 1963 | 1997 | foster social coherence |
| 11303 | 113 | 1 | 4 | 4 | 4 | 5 | 1 | 1963 | 1997 | focus on inhabitants |
| 20101 | 201 | 2 | 4 | 5 | 5 | 3 | 1 | | 1998 | stimulate competing networks |
| 20102 | 201 | 2 | 4 | 5 | 5 | 3 | 1 | | 1998 | stimulate competition |
| 20103 | 201 | 2 | 4 | 5 | 5 | 3 | 1 | | 1998 | frustrate monopolists |

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| 20104 | 201 | 2 | 4 | 5 | 5 | 3 | 1 | 1998 | increase internal communication |
| 20201 | 202 | 2 | 4 | 4 | 4 | 4 | 1 | 1998 | stimulate additional access |
| 20202 | 202 | 2 | 4 | 4 | 4 | 4 | 1 | 1998 | admit more providers |
| 20203 | 202 | 2 | 4 | 4 | 4 | 4 | 0 | 1998 | remove obstructions providers |
| 20204 | 202 | 2 | 4 | 4 | 4 | 4 | 1 | 1998 | increase internal communication |
| 20301 | 203 | 2 | 4 | 5 | 4 | 5 | 1 | 1999 | formulate safety requirements |
| 20302 | 203 | 2 | 4 | 5 | 4 | 5 | 1 | 1999 | stimulate safety consciousness |
| 20303 | 203 | 2 | 4 | 5 | 4 | 5 | 0 | 1999 | international consultation safety |
| 20304 | 203 | 2 | 4 | 5 | 4 | 5 | 0 | 1999 | increase internal communication |

| OptiNo | RespNo | CaseNo | ImpoPr | ImpiPr | ImpoPr | ImpiPo | Implem | Ybirth | Yorg | Option |
|---|---|---|---|---|---|---|---|---|---|---|
| 20401 | 204 | 2 | 4 | 4 | 5 | 4 | 0 | | 1997 | make UMTS available |
| 20402 | 204 | 2 | 4 | 4 | 5 | 4 | 1 | | 1997 | stimulate open platform |
| 20403 | 204 | 2 | 4 | 4 | 5 | 4 | 1 | | 1997 | focus on tasks own department |
| 20404 | 204 | 2 | 4 | 4 | 5 | 4 | 0 | | 1997 | increase internal communication |
| 20701 | 207 | 2 | 4 | 4 | 4 | 5 | 1 | | 1996 | increase wireless access |
| 20702 | 207 | 2 | 4 | 4 | 4 | 5 | 1 | | 1996 | foster use other infrastructure |
| 20703 | 207 | 2 | 4 | 4 | 4 | 5 | 1 | | 1996 | increase competition |
| 20704 | 207 | 2 | 4 | 4 | 4 | 5 | 1 | | 1996 | increase internal communication |
| 20901 | 209 | 2 | 4 | 4 | 4 | 4 | 1 | | 1997 | invest in alternative access |
| 20902 | 209 | 2 | 4 | 4 | 4 | 4 | 1 | | 1997 | make central net public |
| 20903 | 209 | 2 | 4 | 4 | 4 | 4 | 1 | | 1997 | subsidise alternative access |
| 20904 | 209 | 2 | 4 | 4 | 4 | 4 | 1 | | 1997 | increase internal communication |
| 30101 | 301 | 3 | 4 | 2 | | | 0 | 1945 | | recruit in other organisations |
| 30102 | 301 | 3 | 4 | 2 | | | 1 | 1945 | | increase internal training |
| 30201 | 302 | 3 | 5 | 3 | | | 1 | 1974 | | focus on inflow human resources |
| 30202 | 302 | 3 | 5 | 3 | | | 1 | 1974 | | focus on outflow human resources |
| 30301 | 303 | 3 | 5 | 5 | | | 1 | 1972 | 1996 | map quality of human resources |
| 30302 | 303 | 3 | 5 | 5 | | | 1 | 1972 | 1996 | improve conditions recruitment |
| 30401 | 304 | 3 | 4 | 4 | | | 1 | | | increase involvement management |
| 30402 | 304 | 3 | 4 | 4 | | | 1 | | | map individual competencies |
| 30501 | 305 | 3 | 5 | 5 | | | 1 | 1974 | | increase match profile - position |
| 30502 | 305 | 3 | 5 | 5 | | | 1 | 1974 | | recruit right competencies |
| 30601 | 306 | 3 | 5 | 5 | | | 0 | | | involve employees in success |
| 30602 | 306 | 3 | 5 | 5 | | | 1 | | | reduce distance between employees |
| 30901 | 309 | 3 | 5 | 4 | | | 0 | | | steer inflow and outflow human resources |
| 30902 | 309 | 3 | 5 | 4 | | | 1 | | | support career planning |
| 40101 | 401 | 4 | 4 | | | | 1 | 1944 | 1990 | foster maintenance and renovation |
| 40102 | 401 | 4 | 4 | | | | 1 | 1944 | 1990 | more client oriented service |
| 40103 | 401 | 4 | 4 | | | | 0 | 1944 | 1990 | rent increase higher than inflation |
| 40201 | 402 | 4 | 4 | | | | 1 | 1947 | 1982 | foster maintenance and renovation |
| 40202 | 402 | 4 | 4 | | | | 1 | 1947 | 1982 | more client oriented service |
| 40203 | 402 | 4 | 4 | | | | 0 | 1947 | 1982 | rent increase higher than inflation |
| 40301 | 403 | 4 | 4 | | | | 1 | 1938 | 1998 | foster maintenance and renovation |
| 40302 | 403 | 4 | 4 | | | | 1 | 1938 | 1998 | more client oriented service |
| 40303 | 403 | 4 | 4 | | | | 0 | 1938 | 1998 | rent increase higher than inflation |
| 50101 | 501 | 5 | 4 | | 4 | | 1 | 1962 | | foster maintenance and renovation |
| 50102 | 501 | 5 | 4 | | 4 | | 1 | 1962 | | more client oriented service |
| 50103 | 501 | 5 | 4 | | 4 | | 0 | 1962 | | rent increase higher than inflation |
| 50201 | 502 | 5 | 4 | | 5 | | 1 | 1949 | | foster maintenance and renovation |
| 50202 | 502 | 5 | 4 | | 5 | | 1 | 1949 | | more client oriented service |
| 50203 | 502 | 5 | 4 | | 5 | | 0 | 1949 | | rent increase higher than inflation |

| | | | | | | |
|---|---|---|---|---|---|---|
| 50301 | 503 | 5 | 4 | 1 | 1940 | foster maintenance and renovation |
| 50302 | 503 | 5 | 4 | 1 | 1940 | more client oriented service |
| 50303 | 503 | 5 | 4 | 0 | 1940 | rent increase higher than inflation |
| 50401 | 504 | 5 | 4 | 1 | 1956 | foster maintenance and renovation |
| 50402 | 504 | 5 | 4 | 1 | 1956 | more client oriented service |
| 50403 | 504 | 5 | 4 | 0 | 1956 | rent increase higher than inflation |

| OptiNo | ChCat | OpenCom | ClearCom | EqPart | AmOpp | Pragm | AttIdea | Domin | TimePr | Effic | Success |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 10201 | 1 | 4 | 4 | 4 | 3 | 4 | 4 | 1 | 3 | 4 | 4 |
| 10202 | 3 | 4 | 4 | 4 | 3 | 4 | 4 | 1 | 3 | 4 | 4 |
| 10203 | 11 | 4 | 4 | 4 | 3 | 4 | 4 | 1 | 3 | 4 | 4 |
| 10301 | 1 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 |
| 10302 | 3 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 |
| 10303 | 3 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 |
| 10401 | 3 | 4 | 4 | 4 | 2 | 3 | 3 | 2 | 2 | 5 | 4 |
| 10402 | 3 | 4 | 4 | 4 | 2 | 3 | 3 | 2 | 2 | 5 | 4 |
| 10403 | 1 | 4 | 4 | 4 | 2 | 3 | 3 | 2 | 2 | 5 | 4 |
| 10501 | 3 | 4 | 4 | 4 | 4 | 4 | 4 | 3 | 3 | 4 | 4 |
| 10502 | 3 | 4 | 4 | 4 | 4 | 4 | 4 | 3 | 3 | 4 | 4 |
| 10503 | 3 | 4 | 4 | 4 | 4 | 4 | 4 | 3 | 3 | 4 | 4 |
| 10701 | 3 | 4 | 4 | 4 | 4 | 4 | 4 | 2 | 4 | 4 | 4 |
| 10702 | 3 | 4 | 4 | 4 | 4 | 4 | 4 | 2 | 4 | 4 | 4 |
| 10703 | 3 | 4 | 4 | 4 | 4 | 4 | 4 | 2 | 4 | 4 | 4 |
| 10801 | 3 | 3 | 3 | 5 | 4 | 3 | 4 | 3 | 3 | 4 | 4 |
| 10802 | 3 | 3 | 3 | 5 | 4 | 3 | 4 | 3 | 3 | 4 | 4 |
| 10803 | 3 | 3 | 3 | 5 | 4 | 3 | 4 | 3 | 3 | 4 | 4 |
| 10901 | 1 | 4 | 2 | 4 | 4 | 2 | 4 | 4 | 2 | 3 | 4 |
| 10902 | 3 | 4 | 2 | 4 | 4 | 2 | 4 | 4 | 2 | 3 | 4 |
| 10903 | 11 | 4 | 2 | 4 | 4 | 2 | 4 | 4 | 2 | 3 | 4 |
| 11101 | 11 | 4 | 3 | 4 | 4 | 4 | 4 | 4 | 3 | 4 | 3 |
| 11102 | 3 | 4 | 3 | 4 | 4 | 4 | 4 | 4 | 3 | 4 | 3 |
| 11103 | 1 | 4 | 3 | 4 | 4 | 4 | 4 | 4 | 3 | 4 | 3 |
| 11301 | 1 | 4 | 4 | 4 | 4 | 3 | 4 | 4 | 1 | 4 | 4 |
| 11302 | 3 | 4 | 4 | 4 | 4 | 3 | 4 | 4 | 1 | 4 | 4 |
| 11303 | 1 | 4 | 4 | 4 | 4 | 3 | 4 | 4 | 1 | 4 | 4 |
| 20101 | 3 | 4 | 4 | 4 | 3 | 2 | 4 | 3 | 4 | 4 | 4 |
| 20102 | 3 | 4 | 4 | 4 | 3 | 2 | 4 | 3 | 4 | 4 | 4 |
| 20103 | 6 | 4 | 4 | 4 | 3 | 2 | 4 | 3 | 4 | 4 | 4 |
| 20104 | 1 | 4 | 4 | 4 | 3 | 2 | 4 | 3 | 4 | 4 | 4 |
| 20201 | 3 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | | | 4 |
| 20202 | 5 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | | | 4 |
| 20203 | 5 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | | | 4 |
| 20204 | 1 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | | | 4 |
| 20301 | 5 | 3 | 2 | 3 | 3 | 4 | 3 | 2 | 5 | 2 | 2 |
| 20302 | 3 | 3 | 2 | 3 | 3 | 4 | 3 | 2 | 5 | 2 | 2 |
| 20303 | 11 | 3 | 2 | 3 | 3 | 4 | 3 | 2 | 5 | 2 | 2 |
| 20304 | 1 | 3 | 2 | 3 | 3 | 4 | 3 | 2 | 5 | 2 | 2 |
| 20401 | 3 | 5 | 4 | 4 | 4 | 4 | 4 | 3 | 4 | 4 | 4 |
| 20402 | 3 | 5 | 4 | 4 | 4 | 4 | 4 | 3 | 4 | 4 | 4 |
| 20403 | 2 | 5 | 4 | 4 | 4 | 4 | 4 | 3 | 4 | 4 | 4 |
| 20404 | 1 | 5 | 4 | 4 | 4 | 4 | 4 | 3 | 4 | 4 | 4 |

| OptiNo | ChCat | OpenCom | ClearCom | EqPart | AmOpp | Pragm | AttIdea | Domin | TimePr | Effic | Success |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 20701 | 3 | 4 | 3 | 4 | 4 | 3 | 4 | 4 | 4 | 4 | 4 |
| 20702 | 5 | 4 | 3 | 4 | 4 | 3 | 4 | 4 | 4 | 4 | 4 |
| 20703 | 5 | 4 | 3 | 4 | 4 | 3 | 4 | 4 | 4 | 4 | 4 |
| 20704 | 1 | 4 | 3 | 4 | 4 | 3 | 4 | 4 | 4 | 4 | 4 |
| 20901 | 5 | 4 | 4 | 4 | 4 | 4 | 2 | 4 | 5 | 4 | 4 |
| 20902 | 10 | 4 | 4 | 4 | 4 | 4 | 2 | 4 | 5 | 4 | 4 |
| 20903 | 7 | 4 | 4 | 4 | 4 | 4 | 2 | 4 | 5 | 4 | 4 |
| 20904 | 1 | 4 | 4 | 4 | 4 | 4 | 2 | 4 | 5 | 4 | 4 |
| 30101 | 3 | 5 | 5 | 5 | 5 | 4 | 4 | 4 | 1 | 3 | 4 |
| 30102 | 3 | 5 | 5 | 5 | 5 | 4 | 4 | 4 | 1 | 3 | 4 |
| 30201 | 3 | 4 | 4 | 4 | 3 | 4 | 4 | 4 | 2 | 4 | 4 |
| 30202 | 3 | 4 | 4 | 4 | 3 | 4 | 4 | 4 | 2 | 4 | 4 |
| 30301 | 3 | 5 | 4 | 4 | 4 | 4 | 4 | 4 | 3 | 4 | 4 |
| 30302 | 3 | 5 | 4 | 4 | 4 | 4 | 4 | 4 | 3 | 4 | 4 |
| 30401 | 1 | 4 | | | | | | | | | |
| 30402 | 3 | 4 | | | | | | | | | |
| 30501 | 3 | 5 | 5 | 5 | 4 | 5 | 4 | 4 | 2 | 4 | 4 |
| 30502 | 3 | 5 | 5 | 5 | 4 | 5 | 4 | 4 | 2 | 4 | 4 |
| 30601 | 3 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 4 |
| 30602 | 3 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 4 |
| 30901 | 3 | | | | | | | | | | |
| 30902 | 3 | | | | | | | | | | |
| 40101 | 3 | | | | | | | | | | |
| 40102 | 3 | | | | | | | | | | |
| 40103 | 4 | | | | | | | | | | |
| 40201 | 3 | 4 | 4 | 4 | 4 | 4 | 3 | 3 | 4 | 5 | 5 |
| 40202 | 3 | 4 | 4 | 4 | 4 | 4 | 3 | 3 | 4 | 5 | 5 |
| 40203 | 4 | 4 | 4 | 4 | 4 | 4 | 3 | 3 | 4 | 5 | 5 |
| 40301 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 |
| 40302 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 |
| 40303 | 4 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 |
| 50101 | 3 | 3 | 3 | 3 | 2 | 3 | 3 | 2 | 3 | | 3 |
| 50102 | 3 | 3 | 3 | 3 | 2 | 3 | 3 | 2 | 3 | | 3 |
| 50103 | 4 | 3 | 3 | 3 | 2 | 3 | 3 | 2 | 3 | | 3 |
| 50201 | 3 | 4 | 4 | 4 | 4 | 5 | 5 | 3 | 3 | | 4 |
| 50202 | 3 | 4 | 4 | 4 | 4 | 5 | 5 | 3 | 3 | | 4 |
| 50203 | 4 | 4 | 4 | 4 | 4 | 5 | 5 | 3 | 3 | | 4 |
| 50301 | 3 | 4 | 4 | 4 | 2 | 4 | 3 | 2 | 4 | 4 | 4 |
| 50302 | 3 | 4 | 4 | 4 | 2 | 4 | 3 | 2 | 4 | 4 | 4 |
| 50303 | 4 | 4 | 4 | 4 | 2 | 4 | 3 | 2 | 4 | 4 | 4 |
| 50401 | 3 | 4 | 3 | 4 | 4 | 3 | 4 | 2 | 3 | 2 | 2 |
| 50402 | 3 | 4 | 3 | 4 | 4 | 3 | 4 | 2 | 3 | 2 | 2 |
| 50403 | 4 | 4 | 3 | 4 | 4 | 3 | 4 | 2 | 3 | 2 | 2 |

| OptiNo | Mins | Qins | Mcommun | Qcons | Bcons | Qcommit | Mcommit | Proj | Facilit | OppDisc | Diagram | Param | ModAnal | DatAnal | OutAnal |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 10201 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 5 | 5 | 5 | 5 | | | | |
| 10202 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 5 | 5 | 5 | 5 | | | | |
| 10203 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 5 | 5 | 5 | 5 | | | | |
| 10301 | 4 | 3 | 4 | 4 | 4 | 4 | 4 | 5 | 5 | 5 | 5 | | | | |
| 10302 | 4 | 3 | 4 | 4 | 4 | 4 | 4 | 5 | 5 | 5 | 5 | | | | |
| 10303 | 4 | 3 | 4 | 4 | 4 | 4 | 4 | 5 | 5 | 5 | 5 | | | | |
| 10401 | 4 | 4 | 4 | 5 | 5 | 4 | 4 | 5 | 5 | 5 | 5 | | | | |
| 10402 | 4 | 4 | 4 | 5 | 5 | 4 | 4 | 5 | 5 | 5 | 5 | | | | |
| 10403 | 4 | 4 | 4 | 5 | 5 | 4 | 4 | 5 | 5 | 5 | 5 | | | | |
| 10501 | 4 | 5 | 4 | 4 | 4 | 4 | 4 | 3 | 3 | 4 | 3 | | | | |
| 10502 | 4 | 5 | 4 | 4 | 4 | 4 | 4 | 3 | 3 | 4 | 3 | | | | |
| 10503 | 4 | 5 | 4 | 4 | 4 | 4 | 4 | 3 | 3 | 4 | 3 | | | | |
| 10701 | 3 | 3 | 3 | 3 | 3 | 3 | 4 | 5 | 5 | 5 | 5 | | | | |
| 10702 | 3 | 3 | 3 | 3 | 3 | 3 | 4 | 5 | 5 | 5 | 5 | | | | |
| 10703 | 3 | 3 | 3 | 3 | 3 | 3 | 4 | 5 | 5 | 5 | 5 | | | | |
| 10801 | 4 | 4 | 3 | 5 | 4 | 4 | 3 | | 5 | 5 | 5 | | | | |
| 10802 | 4 | 4 | 3 | 5 | 4 | 4 | 3 | | 5 | 5 | 5 | | | | |
| 10803 | 4 | 4 | 3 | 5 | 4 | 4 | 3 | | 5 | 5 | 5 | | | | |
| 10901 | 4 | 3 | 3 | 4 | 3 | 3 | 4 | 5 | 5 | 5 | 0 | | | | |
| 10902 | 4 | 3 | 3 | 4 | 3 | 3 | 4 | 5 | 5 | 5 | 0 | | | | |
| 10903 | 4 | 3 | 3 | 4 | 3 | 3 | 4 | 5 | 5 | 5 | 0 | | | | |
| 11101 | 4 | 4 | 3 | 3 | 4 | 3 | 3 | 3 | 5 | 2 | 2 | | | | |
| 11102 | 4 | 4 | 3 | 3 | 4 | 3 | 3 | 3 | 5 | 2 | 2 | | | | |
| 11103 | 4 | 4 | 3 | 3 | 4 | 3 | 3 | 3 | 5 | 2 | 2 | | | | |
| 11301 | 3 | 4 | 3 | 4 | 4 | 3 | 4 | 3 | 3 | 4 | 1 | | | | |
| 11302 | 3 | 4 | 3 | 4 | 4 | 3 | 4 | 3 | 3 | 4 | 1 | | | | |
| 11303 | 3 | 4 | 3 | 4 | 4 | 3 | 4 | 3 | 3 | 4 | 1 | | | | |
| 20101 | 3 | 2 | 4 | 3 | 4 | 4 | 4 | 3 | 3 | 2 | 0 | | | | |
| 20102 | 3 | 2 | 4 | 3 | 4 | 4 | 4 | 3 | 3 | 2 | 0 | | | | |
| 20103 | 3 | 2 | 4 | 3 | 4 | 4 | 4 | 3 | 3 | 2 | 0 | | | | |
| 20104 | 3 | 2 | 4 | 3 | 4 | 4 | 4 | 3 | 3 | 2 | 0 | | | | |
| 20201 | 3 | 3 | 4 | 4 | 4 | 3 | 3 | | | | | | | | |
| 20202 | 3 | 3 | 4 | 4 | 4 | 3 | 3 | | | | | | | | |
| 20203 | 3 | 3 | 4 | 4 | 4 | 3 | 3 | | | | | | | | |
| 20204 | 3 | 3 | 4 | 4 | 4 | 3 | 3 | | | | | | | | |
| 20301 | 4 | 2 | 2 | 3 | 3 | 2 | 2 | 0 | 0 | 3 | 3 | | | | |
| 20302 | 4 | 2 | 2 | 3 | 3 | 2 | 2 | 0 | 0 | 3 | 3 | | | | |
| 20303 | 4 | 2 | 2 | 3 | 3 | 2 | 2 | 0 | 0 | 3 | 3 | | | | |
| 20304 | 4 | 2 | 2 | 3 | 3 | 2 | 2 | 0 | 0 | 3 | 3 | | | | |
| 20401 | 4 | 3 | 3 | 3 | 4 | 3 | 4 | 5 | 5 | 5 | 5 | | | | |
| 20402 | 4 | 3 | 3 | 3 | 4 | 3 | 4 | 5 | 5 | 5 | 5 | | | | |
| 20403 | 4 | 3 | 3 | 3 | 4 | 3 | 4 | 5 | 5 | 5 | 5 | | | | |
| 20404 | 4 | 3 | 3 | 3 | 4 | 3 | 4 | 5 | 5 | 5 | 5 | | | | |

| OptiNo | Mins | Qins | Mcommun | Qcons | Bcons | Qcommit | Mcommit | Proj | Facilit | OppDisc | Diagram | Param | ModAnal | DatAnal | OutAnal |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 20701 | 4 | 3 | 4 | 4 | 4 | 3 | 3 | 5 | 5 | 3 | 3 | | | | |
| 20702 | 4 | 3 | 4 | 4 | 4 | 3 | 3 | 5 | 5 | 3 | 3 | | | | |
| 20703 | 4 | 3 | 4 | 4 | 4 | 3 | 3 | 5 | 5 | 3 | 3 | | | | |
| 20704 | 4 | 3 | 4 | 4 | 4 | 3 | 3 | 5 | 5 | 3 | 3 | | | | |
| 20901 | 4 | 3 | 4 | 4 | 4 | 2 | 4 | 5 | 5 | 5 | 5 | | | | |
| 20902 | 4 | 3 | 4 | 4 | 4 | 2 | 4 | 5 | 5 | 5 | 5 | | | | |
| 20903 | 4 | 3 | 4 | 4 | 4 | 2 | 4 | 5 | 5 | 5 | 5 | | | | |
| 20904 | 4 | 3 | 4 | 4 | 4 | 2 | 4 | 5 | 5 | 5 | 5 | | | | |
| 30101 | 5 | 5 | 3 | 2 | 4 | 2 | 4 | 4 | 4 | 4 | 4 | 5 | 5 | | |
| 30102 | 5 | 5 | 3 | 2 | 4 | 2 | 4 | 4 | 4 | 4 | 4 | 5 | 5 | | |
| 30201 | 4 | 4 | 4 | 4 | 4 | | 4 | 5 | 5 | 4 | 5 | 4 | 5 | | |
| 30202 | 4 | 4 | 4 | 4 | 4 | | 4 | 5 | 5 | 4 | 5 | 4 | 5 | | |
| 30301 | 4 | 3 | 3 | 3 | 4 | 3 | 4 | 4 | 5 | 4 | 4 | 4 | 3 | | |
| 30302 | 4 | 3 | 3 | 3 | 4 | 3 | 4 | 4 | 5 | 4 | 4 | 4 | 3 | | |
| 30401 | 4 | | | 2 | 4 | 3 | 4 | 4 | 4 | 4 | 4 | | | | |
| 30402 | 4 | | | 2 | 4 | 3 | 4 | 4 | 4 | 4 | 4 | | | | |
| 30501 | 4 | 4 | 3 | 4 | 4 | 4 | 4 | 5 | 5 | 5 | 5 | 4 | | | |
| 30502 | 4 | 4 | 3 | 4 | 4 | 4 | 4 | 5 | 5 | 5 | 5 | 4 | | | |
| 30601 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 5 | 5 | 5 | 3 | 3 | 3 | | |
| 30602 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 5 | 5 | 5 | 3 | 3 | 3 | | |
| 30901 | 4 | 4 | 4 | 4 | 4 | 4 | 2 | 5 | 5 | 3 | 4 | | | | |
| 30902 | 4 | 4 | 4 | 4 | 4 | 4 | 2 | 5 | 5 | 3 | 4 | | | | |
| 40101 | | | | | | | | | | | | | | | |
| 40102 | | | | | | | | | | | | | | | |
| 40103 | | | | | | | | | | | | | | | |
| 40201 | | | | | | | | 5 | 1 | 3 | 3 | | | 1 | 5 |
| 40202 | | | | | | | | 5 | 1 | 3 | 3 | | | 1 | 5 |
| 40203 | | | | | | | | 5 | 1 | 3 | 3 | | | 1 | 5 |
| 40301 | | | | | | | | 2 | 0 | 2 | 1 | | | 0 | 1 |
| 40302 | | | | | | | | 2 | 0 | 2 | 1 | | | 0 | 1 |
| 40303 | | | | | | | | 2 | 0 | 2 | 1 | | | 0 | 1 |
| 50101 | 3 | 4 | 3 | 4 | 3 | 2 | 2 | 2 | 2 | 0 | | | | 3 | 2 |
| 50102 | 3 | 4 | 3 | 4 | 3 | 2 | 2 | 2 | 2 | 0 | | | | 3 | 2 |
| 50103 | 3 | 4 | 3 | 4 | 3 | 2 | 2 | 2 | 2 | 0 | | | | 3 | 2 |
| 50201 | 4 | 4 | 4 | 4 | 4 | 3 | 4 | 5 | 0 | 5 | 5 | | | 5 | 5 |
| 50202 | 4 | 4 | 4 | 4 | 4 | 3 | 4 | 5 | 0 | 5 | 5 | | | 5 | 5 |
| 50203 | 4 | 4 | 4 | 4 | 4 | 3 | 4 | 5 | 0 | 5 | 5 | | | 5 | 5 |
| 50301 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 3 | 5 | 3 | 3 | | | 3 | 3 |
| 50302 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 3 | 5 | 3 | 3 | | | 3 | 3 |
| 50303 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 3 | 5 | 3 | 3 | | | 3 | 3 |
| 50401 | | | | | | | | 3 | 3 | 4 | 0 | | | -3 | -3 |
| 50402 | | | | | | | | 3 | 3 | 4 | 0 | | | -3 | -3 |
| 50403 | | | | | | | | 3 | 3 | 4 | 0 | | | -3 | -3 |

| OptiNo | AIOption | AIGoal | AIValue | AIRisk | AIInfo | AIInteg | AIOutc | AICond | AICont | AICost |
|---|---|---|---|---|---|---|---|---|---|---|
| 10201 | 3 | 4 | 4 | 3 | 2 | 4 | 3 | 3 | 3 | 1 |
| 10202 | 3 | 4 | 4 | 3 | 2 | 4 | 3 | 3 | 3 | 1 |
| 10203 | 3 | 4 | 4 | 3 | 2 | 4 | 3 | 3 | 3 | 1 |
| 10301 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 3 |
| 10302 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 3 |
| 10303 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 3 |
| 10401 | 2 | 2 | 4 | 2 | 4 | 4 | 4 | 4 | 3 | 2 |
| 10402 | 2 | 2 | 4 | 2 | 4 | 4 | 4 | 4 | 3 | 2 |
| 10403 | 2 | 2 | 4 | 2 | 4 | 4 | 4 | 4 | 3 | 2 |
| 10501 | 4 | 4 | 4 | 2 | 3 | 4 | 3 | 3 | 3 | 2 |
| 10502 | 4 | 4 | 4 | 2 | 3 | 4 | 3 | 3 | 3 | 2 |
| 10503 | 4 | 4 | 4 | 2 | 3 | 4 | 3 | 3 | 3 | 2 |
| 10701 | 4 | 4 | 4 | 3 | 3 | 4 | 3 | 4 | 3 | 3 |
| 10702 | 4 | 4 | 4 | 3 | 3 | 4 | 3 | 4 | 3 | 3 |
| 10703 | 4 | 4 | 4 | 3 | 3 | 4 | 3 | 4 | 3 | 3 |
| 10801 | 4 | 4 | 4 | 3 | 3 | 4 | 4 | 4 | 3 | 2 |
| 10802 | 4 | 4 | 4 | 3 | 3 | 4 | 4 | 4 | 3 | 2 |
| 10803 | 4 | 4 | 4 | 3 | 3 | 4 | 4 | 4 | 3 | 2 |
| 10901 | 4 | 4 | 4 | 3 | 3 | 4 | 3 | 4 | 4 | 2 |
| 10902 | 4 | 4 | 4 | 3 | 3 | 4 | 3 | 4 | 4 | 2 |
| 10903 | 4 | 4 | 4 | 3 | 3 | 4 | 3 | 4 | 4 | 2 |
| 11101 | 3 | 4 | 4 | 3 | 4 | 3 | 3 | 3 | 3 | 3 |
| 11102 | 3 | 4 | 4 | 3 | 4 | 3 | 3 | 3 | 3 | 3 |
| 11103 | 3 | 4 | 4 | 3 | 4 | 3 | 3 | 3 | 3 | 3 |
| 11301 | 4 | 4 | 3 | 2 | 3 | 4 | 3 | 3 | 3 | 2 |
| 11302 | 4 | 4 | 3 | 2 | 3 | 4 | 3 | 3 | 3 | 2 |
| 11303 | 4 | 4 | 3 | 2 | 3 | 4 | 3 | 3 | 3 | 2 |
| 20101 | 4 | 3 | 4 | 4 | 3 | 2 | 3 | 4 | 2 | 4 |
| 20102 | 4 | 3 | 4 | 4 | 3 | 2 | 3 | 4 | 2 | 4 |
| 20103 | 4 | 3 | 4 | 4 | 3 | 2 | 3 | 4 | 2 | 4 |
| 20104 | 4 | 3 | 4 | 4 | 3 | 2 | 3 | 4 | 2 | 4 |
| 20201 | 4 | 4 | 4 | 3 | 3 | 3 | 3 | 3 | 3 | 4 |
| 20202 | 4 | 4 | 4 | 3 | 3 | 3 | 3 | 3 | 3 | 4 |
| 20203 | 4 | 4 | 4 | 3 | 3 | 3 | 3 | 3 | 3 | 4 |
| 20204 | 4 | 4 | 4 | 3 | 3 | 3 | 3 | 3 | 3 | 4 |
| 20301 | 2 | 2 | 2 | 2 | 2 | 2 | 3 | 3 | 1 | 4 |
| 20302 | 2 | 2 | 2 | 2 | 2 | 2 | 3 | 3 | 1 | 4 |
| 20303 | 2 | 2 | 2 | 2 | 2 | 2 | 3 | 3 | 1 | 4 |
| 20304 | 2 | 2 | 2 | 2 | 2 | 2 | 3 | 3 | 1 | 4 |
| 20401 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 |
| 20402 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 |
| 20403 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 |
| 20404 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 |

| OptiNo | AIOption | AIGoal | AIValue | AIRisk | AIInfo | AIInteg | AIOutc | AICond | AICont | AICost |
|---|---|---|---|---|---|---|---|---|---|---|
| 20701 | 2 | 2 | 4 | 2 | 3 | 4 | 3 | 4 | 4 | 4 |
| 20702 | 2 | 2 | 4 | 2 | 3 | 4 | 3 | 4 | 4 | 4 |
| 20703 | 2 | 2 | 4 | 2 | 3 | 4 | 3 | 4 | 4 | 4 |
| 20704 | 2 | 2 | 4 | 2 | 3 | 4 | 3 | 4 | 4 | 4 |
| 20901 | 5 | 5 | 5 | 2 | 4 | 4 | 2 | 2 | 2 | 2 |
| 20902 | 5 | 5 | 5 | 2 | 4 | 4 | 2 | 2 | 2 | 2 |
| 20903 | 5 | 5 | 5 | 2 | 4 | 4 | 2 | 2 | 2 | 2 |
| 20904 | 5 | 5 | 5 | 2 | 4 | 4 | 2 | 2 | 2 | 2 |
| 30101 | 4 | | 2 | 5 | | 2 | | 4 | | 4 |
| 30102 | 4 | | 2 | 5 | | 2 | | 4 | | 4 |
| 30201 | 3 | 3 | 4 | 4 | 2 | 4 | 4 | 2 | 2 | 2 |
| 30202 | 3 | 3 | 4 | 4 | 2 | 4 | 4 | 2 | 2 | 2 |
| 30301 | 2 | 5 | 2 | 1 | 2 | 4 | | 1 | | 1 |
| 30302 | 2 | 5 | 2 | 1 | 2 | 4 | | 1 | | 1 |
| 30401 | | | | | | | | | | |
| 30402 | | | | | | | | | | |
| 30501 | 2 | 4 | 2 | 2 | 2 | 4 | | | | 2 |
| 30502 | 2 | 4 | 2 | 2 | 2 | 4 | | | | 2 |
| 30601 | 4 | 4 | 4 | 2 | 2 | 4 | 4 | 2 | 2 | 2 |
| 30602 | 4 | 4 | 4 | 2 | 2 | 4 | 4 | 2 | 2 | 2 |
| 30901 | | 4 | 4 | 2 | 4 | | | | | 2 |
| 30902 | | 4 | 4 | 2 | 4 | | | | | 2 |
| 40101 | | | | | | | | | | |
| 40102 | | | | | | | | | | |
| 40103 | | | | | | | | | | |
| 40201 | | | | | | | | | | |
| 40202 | | | | | | | | | | |
| 40203 | | | | | | | | | | |
| 40301 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 |
| 40302 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 |
| 40303 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 |
| 50101 | 4 | 4 | 4 | 2 | 3 | 4 | 4 | 3 | 3 | 2 |
| 50102 | 4 | 4 | 4 | 2 | 3 | 4 | 4 | 3 | 3 | 2 |
| 50103 | 4 | 4 | 4 | 2 | 3 | 4 | 4 | 3 | 3 | 2 |
| 50201 | 5 | 4 | 4 | 4 | 4 | 5 | 4 | 4 | 4 | 4 |
| 50202 | 5 | 4 | 4 | 4 | 4 | 5 | 4 | 4 | 4 | 4 |
| 50203 | 5 | 4 | 4 | 4 | 4 | 5 | 4 | 4 | 4 | 4 |
| 50301 | 5 | 4 | 4 | 4 | 4 | 4 | 3 | 3 | 4 | 4 |
| 50302 | 5 | 4 | 4 | 4 | 4 | 4 | 3 | 3 | 4 | 4 |
| 50303 | 5 | 4 | 4 | 4 | 4 | 4 | 3 | 3 | 4 | 4 |
| 50401 | 4 | 2 | 3 | 2 | 2 | 2 | 2 | 2 | | 2 |
| 50402 | 4 | 2 | 3 | 2 | 2 | 2 | 2 | 2 | | 2 |
| 50403 | 4 | 2 | 3 | 2 | 2 | 2 | 2 | 2 | | 2 |

| OptiNo | AttbPr | AttgPr | NormPr | ContePr | ContnPr | OptagPr | OptsngPr | OptpcgPr | IntiPr | IntePr |
|---|---|---|---|---|---|---|---|---|---|---|
| 10201 | 4 | 5 | 5 | 3 | 4 | 20.00 | 6.33 | 0.33 | 5 | 5 |
| 10202 | 4 | 4 | 4 | 2 | 3 | 17.33 | 6.00 | 0.33 | 5 | 4 |
| 10203 | 4 | 4 | 5 | 4 | 4 | 16.67 | 5.00 | 0.33 | 5 | 4 |
| 10301 | 5 | 5 | 4 | 2 | 3 | 10.33 | 0.00 | 21.00 | 5 | 5 |
| 10302 | 5 | 5 | 4 | 2 | 3 | 9.33 | 0.00 | 21.00 | 5 | 5 |
| 10303 | 5 | 5 | 4 | 2 | 3 | 9.00 | 0.00 | 17.00 | 5 | 5 |
| 10401 | 4 | 4 | 5 | 2 | 3 | -6.00 | 2.67 | 2.00 | 5 | 5 |
| 10402 | 5 | 5 | 4 | 2 | 2 | -11.00 | 11.00 | 2.00 | 3 | 3 |
| 10403 | 4 | 4 | 4 | 2 | 2 | -11.00 | 6.00 | 3.67 | 3 | 4 |
| 10501 | 3 | 4 | 4 | 3 | 4 | 7.00 | 2.67 | 7.00 | 5 | 4 |
| 10502 | 3 | 4 | 4 | 3 | 4 | 7.00 | 0.00 | 9.00 | 4 | 4 |
| 10503 | 4 | 4 | 4 | 4 | 4 | 8.00 | 0.00 |  | 4 | 4 |
| 10701 | 4 | 4 | 4 | 2 | 3 | 11.00 | 11.00 | 4.00 | 4 | 4 |
| 10702 | 4 | 4 | 4 | 4 | 3 | 11.00 | 11.00 | 0.67 | 4 | 4 |
| 10703 | 5 | 5 | 4 | 1 | 3 | 11.00 | 11.00 | 0.67 | 5 | 4 |
| 10801 | 4 | 4 | 4 | 2 | 3 | 11.00 | 0.00 | 10.00 | 4 | 4 |
| 10802 | 5 | 5 | 4 | 4 | 3 | 11.00 | 0.00 | 1.67 | 4 | 4 |
| 10803 | 4 | 4 | 3 | 1 | 3 | 11.00 | 0.00 | 1.67 | 3 | 4 |
| 10901 | 5 | 4 | 4 | 2 | 4 | 7.33 | 18.67 | -1.00 | 4 | 4 |
| 10902 | 4 | 4 | 4 | 2 | 2 | 7.33 | 18.67 | 1.00 | 5 | 4 |
| 10903 | 3 | 3 | 3 | 4 | 5 | 4.00 | 12.00 |  | 4 | 4 |
| 11101 | 4 | 4 | 5 | 4 | 3 | 18.00 | 14.67 | 3.67 | 5 | 4 |
| 11102 | 4 | 4 | 5 | 3 | 4 | 18.00 | 14.67 | 3.67 | 5 | 5 |
| 11103 | 4 | 4 | 5 | 4 | 4 | 13.33 | 14.67 | 3.67 | 5 | 5 |
| 11301 | 4 |  | 4 | 3 | 4 | 9.00 | 10.33 | 0.00 | 4 | 4 |
| 11302 | 4 |  | 4 | 2 | 2 | 9.33 | 10.00 | 0.00 | 4 | 4 |
| 11303 | 4 |  | 4 | 3 | 2 | 8.33 | 10.00 | 0.00 | 4 | 4 |
| 20101 | 5 | 4 | 2 | 4 | 3 | -2.14 | -7.17 | -17.33 | 5 | 5 |
| 20102 | 4 | 4 | 4 | 4 | 4 | -3.86 | 0.00 | -24.00 | 4 | 4 |
| 20103 | 2 | 1 | 2 | 2 | 4 | -7.29 | -15.67 | -3.33 | 1 | 1 |
| 20104 | 4 | 4 | 4 | 2 | 3 |  |  |  | 4 | 5 |
| 20201 | 4 | 4 | 3 | 2 | 3 | 5.71 | 3.33 | 0.00 | 4 | 4 |
| 20202 | 4 | 4 | 3 | 4 | 3 | -2.71 | 3.33 | 0.00 | 4 | 4 |
| 20203 | 4 | 4 | 4 | 3 | 3 | 3.00 | 3.33 | 0.00 | 4 | 4 |
| 20204 | 4 | 4 | 4 | 3 | 3 |  |  |  | 4 | 4 |
| 20301 | 4 | 3 | 4 | 3 | 3 | 12.29 | 14.00 | 6.67 | 4 | 4 |
| 20302 | 4 | 4 | 4 | 3 | 3 | 2.71 | 4.83 | -10.00 | 4 | 4 |
| 20303 | 5 | 3 | 3 | 2 | 2 | 12.00 | 10.33 | 6.67 | 5 | 4 |
| 20304 | 4 | 4 | 4 | 2 | 3 |  |  |  | 5 | 4 |
| 20401 | 5 | 4 | 1 | 4 | 1 | -6.67 | -15.67 | -7.33 | 2 | 1 |
| 20402 | 4 | 4 | 3 | 2 | 3 | -10.67 | -3.67 | 7.33 | 4 | 4 |
| 20403 | 5 | 5 | 4 | 2 | 2 | -5.50 | 3.83 | 4.33 | 5 | 5 |
| 20404 | 4 | 4 | 3 | 4 | 3 |  |  |  | 4 | 4 |

| OptiNo | AttbPr | AttgPr | NormPr | ContePr | ContnPr | OptagPr | OptsngPr | OptpcgPr | IntiPr | IntePr |
|---|---|---|---|---|---|---|---|---|---|---|
| 20701 | 5 | | 4 | 5 | 3 | -1.14 | -2.83 | -24.67 | 5 | 5 |
| 20702 | 5 | | 4 | 3 | 3 | -5.29 | 5.80 | 7.33 | 4 | 3 |
| 20703 | 4 | | 4 | 2 | 3 | -5.14 | -4.50 | -14.00 | 3 | |
| 20704 | 4 | 4 | 4 | 4 | 4 | | | | 5 | 4 |
| 20901 | 2 | 2 | 1 | 1 | 3 | -13.71 | -19.33 | 7.33 | 2 | 2 |
| 20902 | 5 | 5 | 1 | 2 | 2 | -8.29 | -21.67 | 0.00 | 3 | 3 |
| 20903 | 5 | 3 | 4 | 4 | 3 | -10.86 | -1.67 | -3.67 | 4 | 4 |
| 20904 | 5 | 4 | 5 | 4 | 4 | | | | 5 | 5 |
| 30101 | 4 | | 4 | 2 | 2 | 6.00 | 20.00 | 10.00 | | |
| 30102 | 5 | | 4 | 4 | 4 | 16.00 | 14.00 | 6.00 | | |
| 30201 | 4 | 3 | 4 | 2 | 2 | 10.50 | 14.00 | 0.00 | 5 | |
| 30202 | 4 | 4 | 2 | 1 | 4 | 15.00 | 14.00 | 0.00 | 5 | |
| 30301 | 5 | 4 | 4 | 3 | 3 | 4.00 | 19.00 | 18.00 | 5 | |
| 30302 | 5 | 3 | 4 | 2 | 2 | 4.00 | 17.00 | 9.00 | 2 | |
| 30401 | 5 | | 4 | 3 | 2 | 12.00 | 22.00 | 9.00 | | |
| 30402 | 5 | | 3 | 4 | 1 | 2.00 | 22.00 | 12.00 | | |
| 30501 | 4 | 3 | 4 | 2 | 3 | 18.00 | 15.50 | 13.00 | 4 | |
| 30502 | 5 | 4 | 3 | 1 | 2 | 16.00 | 16.00 | 16.00 | 5 | |
| 30601 | 4 | 3 | 4 | 2 | 4 | 11.50 | 6.00 | 2.00 | 4 | |
| 30602 | 5 | 5 | 4 | 2 | 4 | 11.50 | 11.00 | 2.00 | 4 | |
| 30901 | 5 | 4 | 2 | 2 | 3 | 20.00 | 16.50 | 3.00 | 4 | |
| 30902 | 5 | 2 | 2 | 1 | 4 | 14.00 | 11.50 | 4.00 | 3 | |
| 40101 | 4 | 4 | 4 | 3 | 5 | 13.33 | 11.00 | 7.50 | 5 | 5 |
| 40102 | 5 | 5 | 5 | 4 | 2 | 13.33 | 11.00 | 8.00 | 5 | 5 |
| 40103 | 3 | 3 | 1 | 4 | 4 | 8.33 | 1.67 | 7.00 | 1 | 1 |
| 40201 | 4 | 4 | 3 | 3 | 3 | -0.67 | 7.00 | 9.17 | 4 | 4 |
| 40202 | 5 | 5 | 4 | 3 | 3 | 0.00 | 8.00 | 7.83 | 4 | 4 |
| 40203 | 2 | 1 | 1 | 1 | 1 | -0.17 | -1.17 | 2.67 | 1 | 1 |
| 40301 | 3 | 3 | 3 | 3 | 3 | 9.67 | 5.83 | 9.67 | 4 | 3 |
| 40302 | 4 | 4 | 4 | 4 | 4 | 10.00 | 6.33 | 9.67 | 4 | 4 |
| 40303 | 2 | 2 | 2 | 2 | 3 | 6.50 | 3.67 | 9.00 | 2 | 2 |
| 50101 | 2 | 3 | 3 | 3 | 3 | 5.33 | 4.33 | 8.33 | | 3 |
| 50102 | 4 | 4 | 3 | 2 | 2 | 5.00 | 5.00 | 9.67 | 5 | 4 |
| 50103 | 4 | 4 | 3 | 4 | 2 | 3.83 | 1.83 | 6.00 | 4 | 4 |
| 50201 | 4 | 4 | 2 | 3 | 3 | 15.40 | 11.60 | 12.33 | 5 | 4 |
| 50202 | 5 | 5 | 4 | 4 | 2 | 13.80 | 13.20 | 14.33 | 5 | 4 |
| 50203 | 4 | 2 | 2 | 2 | 4 | 10.50 | 6.00 | 10.33 | 4 | 4 |
| 50301 | 2 | 3 | 2 | 2 | 4 | 2.83 | 6.00 | 4.67 | 2 | 2 |
| 50302 | 4 | 5 | 4 | 4 | 2 | 3.67 | 11.00 | 8.00 | 4 | 4 |
| 50303 | 4 | 4 | 4 | 4 | 2 | 1.17 | 6.00 | 8.00 | 4 | 4 |
| 50401 | 3 | 3 | 3 | 3 | 3 | 5.00 | 3.83 | 5.17 | 4 | 4 |
| 50402 | 4 | 4 | 4 | 3 | 3 | 5.50 | 4.50 | 6.50 | 4 | 4 |
| 50403 | 4 | 4 | 4 | 4 | 2 | 4.00 | 2.33 | 7.00 | 5 | 5 |

| OptiNo | AttbPo | AttgPo | NormPo | ContePo | ContnPo | OptagPo | OptsngPo | OptpcgPo | IntiPo | IntePo |
|---|---|---|---|---|---|---|---|---|---|---|
| 10201 | 5 | 5 | 5 | 2 | 3 | 20.00 | 3.67 | 0.00 | 5 | 5 |
| 10202 | 4 | 4 | 4 | 2 | 3 | 20.00 | 3.33 | 0.00 | 5 | 5 |
| 10203 | 4 | 4 | 4 | 3 | 3 | 20.00 | 3.00 | 0.00 | 5 | 4 |
| 10301 | 5 | 5 | 4 | 4 | 5 | 19.33 | 0.00 | 22.00 | 5 | 5 |
| 10302 | 5 | 5 | 4 | 2 | 4 | 16.67 | 0.00 | 21.33 | 5 | 5 |
| 10303 | 3 | 4 | 3 | 2 | 4 | 16.00 | 0.00 | 18.00 | 5 | 5 |
| 10401 | 5 | 4 | 4 | 3 | 2 | 11.00 | 22.00 | 3.67 | 5 | 5 |
| 10402 | 4 | 4 | 3 | 4 | 2 | 6.00 |  | 0.00 | 5 | 4 |
| 10403 | 5 | 5 | 4 | 2 | 2 | 6.00 | 11.00 | 0.00 | 4 | 3 |
| 10501 | 4 | 4 | 4 | 3 | 3 | 9.00 | 8.50 | 3.00 | 5 | 4 |
| 10502 | 4 | 4 | 3 | 2 | 3 | 9.00 | 9.00 | 3.00 | 4 | 4 |
| 10503 |  |  |  |  |  |  |  | 0.00 |  |  |
| 10701 | 4 | 4 | 4 | 3 | 3 | 11.00 | 0.00 | 0.00 | 4 | 4 |
| 10702 | 4 | 4 | 4 | 3 | 3 | 11.00 | 0.00 | 0.00 | 4 | 4 |
| 10703 | 4 | 4 | 4 | 3 | 4 | 11.00 | 0.00 | 0.00 | 4 | 4 |
| 10801 | 5 | 5 | 5 | 3 | 2 | 22.00 | 7.33 | 2.00 | 4 | 4 |
| 10802 | 4 | 4 | 5 | 4 | 3 | 22.00 | 7.33 | 0.33 | 4 | 4 |
| 10803 | 4 | 4 | 5 | 4 | 3 | 22.00 | 7.33 | 0.33 | 4 | 4 |
| 10901 | 4 |  | 4 | 2 | 3 |  | 11.33 | 0.50 | 5 | 5 |
| 10902 | 4 |  | 4 | 3 | 3 |  | 14.67 | 0.50 | 4 | 5 |
| 10903 | 4 |  | 3 | 4 | 4 |  | 11.33 | 3.00 | 4 | 5 |
| 11101 | 4 | 4 | 5 | 4 | 3 | 16.00 | 7.33 | 3.67 | 5 | 5 |
| 11102 | 4 | 4 | 4 | 2 | 3 | 16.67 | 7.33 | 3.67 | 5 | 4 |
| 11103 | 4 | 4 | 5 | 3 | 3 | 14.67 | 7.33 | 2.00 | 5 | 4 |
| 11301 | 4 |  | 4 | 3 | 4 | 11.00 | 7.33 | 3.33 | 4 | 4 |
| 11302 | 4 |  | 4 | 2 | 2 | 13.33 | 6.33 | 2.67 | 4 | 4 |
| 11303 | 4 |  | 3 | 3 | 2 | 13.33 | 7.00 | 1.00 | 4 | 4 |
| 20101 | 5 | 4 | 3 | 2 | 2 | 0.86 | -10.00 | -16.67 | 4 | 4 |
| 20102 | 3 | 2 | 2 |  |  | -16.00 | -4.83 | -13.33 | 2 | 4 |
| 20103 | 2 | 2 | 3 | 2 | 1 | -12.71 | -7.50 | -21.00 | 2 | 2 |
| 20104 | 4 | 4 | 5 | 4 | 2 |  |  |  | 4 | 4 |
| 20201 | 4 | 4 | 4 | 3 | 3 | -7.14 | 10.00 | -10.67 | 4 | 4 |
| 20202 | 4 | 4 | 4 | 3 | 3 | -1.43 | 10.00 | -7.33 | 4 | 4 |
| 20203 | 4 | 4 | 4 | 3 | 3 | -2.86 | 10.00 | -11.00 | 4 | 4 |
| 20204 | 4 | 4 | 4 | 3 | 3 |  |  |  | 4 | 4 |
| 20301 | 4 | 4 | 3 | 3 | 3 | -2.29 | -6.00 | 3.67 | 4 | 4 |
| 20302 | 4 | 4 | 4 | 3 | 4 | 0.43 | -3.00 | 3.67 | 4 | 4 |
| 20303 | 2 | 2 | 2 | 1 | 2 | 0.00 | -23.60 | -7.33 | 2 | 2 |
| 20304 | 3 | 3 | 2 | 4 | 3 |  |  |  | 3 | 3 |
| 20401 | 5 | 5 | 2 | 4 | 4 | 0.29 | -10.33 | 4.00 | 4 | 4 |
| 20402 | 4 | 4 | 4 | 2 | 4 | -1.29 | -5.33 | 7.33 | 5 | 4 |
| 20403 | 4 | 4 | 4 | 2 | 2 | -1.29 | 4.00 | 7.33 | 5 | 4 |
| 20404 | 4 | 4 | 4 | 4 | 4 |  |  |  | 4 | 4 |

| OptiNo | AttbPo | AttgPo | NormPo | ContePo | ContnPo | OptagPo | OptsngPo | OptpcgPo | IntiPo | IntePo |
|---|---|---|---|---|---|---|---|---|---|---|
| 20701 | 5 | 5 | 4 | 4 | 4 | -6.71 | 17.00 | -22.00 | 4 | 4 |
| 20702 | 5 | 5 | 3 | 3 | 3 | -1.29 | 5.33 | -3.67 | 4 | 3 |
| 20703 | 5 | 5 | 2 | 2 | 4 | -4.14 | -1.67 | 7.33 | 4 | 3 |
| 20704 | 4 | 4 | 4 | 4 | 5 | | | | 4 | 5 |
| 20901 | 1 | 2 | 1 | 1 | 1 | 2.86 | 0.00 | 4.00 | 1 | 1 |
| 20902 | 2 | 2 | 1 | 1 | 3 | 8.29 | 0.00 | -19.33 | 2 | 1 |
| 20903 | 5 | 4 | 4 | 2 | 2 | 0.00 | 16.33 | 7.33 | 5 | 4 |
| 20904 | 5 | 5 | 5 | 4 | 3 | | | | 5 | 5 |
| 30101 | 4 | 3 | 5 | | 1 | 17.00 | 22.00 | 10.00 | | |
| 30102 | 5 | 5 | 4 | 3 | 1 | 20.00 | 22.00 | 10.00 | | |
| 30201 | 4 | 5 | 3 | 4 | 4 | 14.00 | 0.00 | 0.00 | 4 | |
| 30202 | 4 | 4 | 4 | 1 | 4 | 16.00 | 0.50 | 1.00 | 5 | |
| 30301 | 5 | 5 | 4 | 3 | 3 | 12.00 | 16.00 | 20.00 | 3 | |
| 30302 | 5 | 4 | 4 | 2 | 2 | 4.00 | 21.00 | 8.00 | 4 | |
| 30401 | 5 | 3 | 4 | 4 | 4 | 6.00 | 21.00 | 17.00 | 4 | |
| 30402 | 5 | 5 | 5 | 4 | 5 | 2.00 | 22.00 | 17.00 | 5 | |
| 30501 | 5 | 5 | 4 | 2 | 3 | 19.00 | 19.00 | 3.00 | 4 | |
| 30502 | 5 | 5 | 4 | 4 | 3 | 12.00 | 21.00 | 6.00 | 5 | |
| 30601 | 4 | 4 | 4 | 3 | 4 | 12.00 | 22.00 | -3.50 | 4 | 5 |
| 30602 | 3 | 5 | 4 | 2 | 2 | 12.00 | 22.00 | -2.00 | 4 | 4 |
| 30901 | 5 | 5 | 3 | 2 | 3 | 21.00 | 10.00 | 11.50 | 5 | |
| 30902 | 4 | 4 | 5 | 2 | 2 | 12.00 | 7.50 | 3.00 | 4 | |
| 40101 | 4 | 4 | 4 | 2 | 5 | 16.00 | 16.50 | 22.00 | 5 | 5 |
| 40102 | 4 | 4 | 5 | 2 | 4 | 12.50 | 16.50 | | 5 | 5 |
| 40103 | 2 | 2 | 1 | 2 | 2 | 5.50 | 1.50 | | 1 | 1 |
| 40201 | 3 | 4 | 2 | 3 | 2 | 2.50 | 9.83 | 14.17 | 3 | 3 |
| 40202 | 4 | 4 | 4 | 4 | 4 | 4.67 | 11.00 | 15.83 | 4 | 4 |
| 40203 | 1 | 1 | 1 | 1 | 1 | 1.17 | 0.17 | 1.50 | 1 | 1 |
| 40301 | 3 | 3 | 3 | 3 | 3 | 1.67 | 0.33 | 1.00 | 3 | 3 |
| 40302 | 3 | 3 | 3 | 3 | 3 | 1.83 | 0.50 | 1.00 | 3 | 4 |
| 40303 | 2 | 2 | 2 | 3 | 3 | 0.33 | -0.50 | 1.00 | 2 | 2 |
| 50101 | 4 | 4 | 4 | 3 | 4 | 10.00 | 8.00 | 7.67 | 5 | 5 |
| 50102 | 4 | 4 | 4 | 2 | 2 | 9.67 | 8.00 | 8.00 | 5 | 5 |
| 50103 | 2 | 2 | 2 | 4 | 3 | 7.67 | 0.00 | 8.00 | 2 | 2 |
| 50201 | 4 | 4 | 4 | 3 | 4 | 11.83 | 9.33 | 12.33 | 4 | 4 |
| 50202 | 4 | 4 | 5 | 4 | 4 | 11.00 | 10.17 | 12.33 | 4 | 4 |
| 50203 | 3 | 2 | 2 | 2 | 2 | 5.17 | 2.67 | 5.67 | 2 | 2 |
| 50301 | 3 | 3 | 4 | 4 | 4 | 6.00 | 11.00 | -0.33 | 2 | |
| 50302 | 4 | 4 | 5 | 5 | 4 | 7.00 | 11.00 | -0.33 | 5 | |
| 50303 | 4 | 4 | 5 | 4 | 4 | 5.33 | 8.33 | 4.00 | 5 | |
| 50401 | | | | | | | | | | |
| 50402 | | | | | | | | | | |
| 50403 | | | | | | | | | | |

*Samenvatting*

# Group model building als wederzijdse overreding

Dit onderzoek richt zich op de effecten van het maken van modellen van organisatieproblemen. Onderzoekers en consultants in dit veld verwachten dat door het maken van modellen beslissingen beter worden en de kans op daadwerkelijke implementatie van een beslissing groter wordt. In deze studie wordt het effect van modelbouw vanuit twee perspectieven bekeken: een theoretisch en een empirisch perspectief. Belangrijke vragen met betrekking tot de theorie zijn de volgende: hoe worden beslissingen in organisaties eigenlijk gemaakt? Hoe zou optimale besluitvorming er uitzien? Welke methoden zijn er voor het ondersteunen van besluitvorming in organisaties, of meer concreet: welke assumpties liggen aan de methoden ten grondslag, hoe ziet de toepassing van een methode op een concreet organisatieprobleem er uit, welke resultaten verwachten de gebruikers van een dergelijke methode? Een beschrijving van deze onderwerpen laat zien dat er verschillende en heel uiteenlopende methoden voor het ondersteunen van besluitvorming in organisaties bestaan, waarvan modelbouw er één is. De toepassing van een methode zal daarnaast altijd aangepast zijn aan het specifieke probleem en de specifieke organisatie waarin het probleem zich voordoet. Het is daarom moeilijk in algemene termen te spreken over de effecten van besluitvormingsondersteunende methoden. Om de complexiteit van het onderwerp terug te brengen, wordt in het vervolg van de studie modelbouw centraal gesteld.
Het tweede perspectief richt zich op het meten van de effecten van modelbouw. Een van de conclusies van de theoretische bespreking is dat de doelen en elementen van besluitvormingsondersteunende methoden, en hun onderlinge relaties, niet duidelijk zijn omschreven. Belangrijke doelen, zoals consensus of het vergroten van inzicht in het probleem worden niet duidelijk gedefinieerd. In de literatuur over methoden is niet terug te vinden hoe een methode precies zorgt voor bijvoorbeeld het totstandkomen van consensus. En alhoewel doelen duidelijk gerelateerd lijken te zijn, wordt bijvoorbeeld de invloed van inzicht en consensus op commitment niet uitgewerkt. In het tweede deel van de studie worden modellen uit de sociale psychologie gebruikt om centrale begrippen te definiëren, relaties aan te geven en elementen en doelen meetbaar te maken. Dit raamwerk van variabelen en relaties wordt getest in vijf organisaties die modelbouw toepassen op actuele en complexe problemen.

Het *tweede hoofdstuk* vormt de inleiding op het theoretische perspectief. Allereerst komt hierin de literatuur rond besluitvorming aan de orde. Besluitvorming wordt bekeken vanuit een descriptief en een prescriptief oogpunt, op het niveau van het

individu, de groep en de organisatie. Descriptieve studies laten zien hoe besluitvorming in de praktijk verloopt. Prescriptieve studies geven aan hoe optimale besluitvorming eruitziet, of geven meer praktische richtlijnen voor het ondersteunen van besluitvorming. In deze laatste categorie vinden we beschrijvingen van een aantal methoden om groepen te ondersteunen in het nemen van besluiten. Uit deze methoden wordt zoals gezegd modelbouw gekozen als focus voor het vervolg van de studie.
Er is een aantal redenen om modelbouw te kiezen boven een van de andere methoden. Modelbouw wordt gebruikt in complexe en urgente problemen, en richt zich op het creëren van commitment aan acties om het probleem aan te pakken. Bij het maken van het model worden die organisatieleden betrokken die kennis of verantwoordelijkheid ten aanzien van het gemodelleerde probleem hebben. De deelnemers aan het modelbouwproces worden begeleid door een zogenaamde facilitator, die neutraal staat ten opzichte van de inhoud en alleen let op de structuur en het proces van discussie. Ten opzichte van andere methoden is in de literatuur rond modelbouw de rol van de facilitator relatief goed uitgewerkt. Daarnaast is modelbouw de enige methode voor het ondersteunen van groepsbesluitvorming die faciliteren combineert met kwantitatieve modelbouw. Het gebruik van kwantitatieve modellen maakt het mogelijk een relatie te leggen tussen de structuur en het gedrag van een probleem. Aangezien modelbouw al enige decennia in de participatieve vorm toegepast wordt, is er inmiddels veel kennis opgebouwd waarop deze studie kan voortbouwen. De laatste reden om modelbouw te kiezen is praktisch van aard. De onderzoeker heeft ervaring met het toepassen van modelbouw, wat relevant is omdat methoden en procedures die in de boeken beschreven staan niet op alle vragen die een praktijktoepassing oproept, antwoord geven.
Het vervolg van hoofdstuk twee beschrijft modelbouw. De vorm van modelbouw die centraal staat in deze studie is group model building, een combinatie van system dynamics modelbouw en faciliteren. Deze twee componenten en verschillende manieren waarop ze worden gecombineerd, worden toegelicht. Nadat de interventie beschreven is, is de volgende vraag in welke situatie modelbouw gebruikt wordt. Dit geeft aanleiding tot een omschrijving van complexe organisatieproblemen en de volgende vraag, wat modelbouwers proberen te bereiken in een dergelijke situatie. De vraag naar de beoogde resultaten van modelbouw vereist een duidelijke definitie van doelen, de manier waarop geprobeerd wordt deze te bereiken en onderlinge relaties. Het hoofdstuk eindigt met een beschrijving van elementen van de methode en doelen, zoals die te vinden is in de literatuur rond modelbouw.

*Hoofdstuk drie* vervolgt de discussie door de empirische literatuur rond de toepassing van modelbouw te analyseren. Voordat aan een nieuw onderzoek wordt begonnen, is het nuttig om de resultaten van voorgaande studies over de effectiviteit van

modelbouw op een rij te zetten. Daartoe worden publicaties over de toepassing van modelbouw in complexe organisatieproblemen verzameld en vergeleken. Een aantal vragen wordt behandeld. Zijn er resultaten van modelbouw die regelmatig gevonden worden, voor uiteenlopende organisaties en soorten problemen? Maakt de precieze vorm van modelbouw, bijvoorbeeld of grote gedetailleerde modellen of juist kleine modellen worden gebruikt, uit voor de resultaten? De antwoorden op deze vragen wijzen in de richting van specifieke combinaties van context (kenmerken van de organisatie en het probleem), mechanisme (hoe modelbouw wordt toegepast) en resultaten (effecten van modelbouw).
Een vraag waarop deze literatuur geen antwoord geeft, is hoe de onderdelen van modelbouw nu precies bijdragen aan de effecten. Met andere woorden, om inzicht te krijgen waarom het mechanisme 'modelbouw' werkt, is literatuur uit een ander gebied noodzakelijk.

In *hoofdstuk vier* worden theorieën uit de sociale psychologie gebruikt om een eerste conceptuele model van effectiviteit van modelbouw te formuleren. De centrale doelen van modelbouw, zoals consensus en commitment, hebben een duidelijk equivalent in sociaal psychologische theorieën. De theorie van gepland gedrag (Ajzen, 1991; 2001) wordt gebruikt om een relatie te leggen tussen doelen van modelbouw onderling. Deze theorie richt zich op de relatie tussen overtuigingen (cognitie), evaluaties en gedrag. Een voorbeeld van een overtuiging is de verwachting van een human resources manager, dat loopbaanbegeleiding tot een snellere doorstroom van personeelsleden naar hogere functies zal leiden. Een voorbeeld van een evaluatie is de mate waarin 'loopbaanbegeleiding' goed of slecht wordt gevonden.
Theorieën over overreding (Chaiken, Lieberman and Eagly, 1989; Petty and Cacioppo, 1986) worden gebruikt om te beschrijven hoe modelbouw deelnemers beïnvloedt, met name ten aanzien van hun overtuigingen (inzicht in het probleem) en evaluaties. Theorieën over overreding beschrijven hoe overtuigingen en evaluaties veranderen onder invloed van informatie en andere kenmerken van een boodschap. Als de human resource manager uit het bovenstaande voorbeeld in het modelbouwproces nieuwe en positieve informatie krijgt over loopbaanbegeleiding, is de verwachting dat zijn evaluatie van loopbaanbegeleiding positiever wordt. Volgens deze theorieën heeft deze informatie echter alleen effect wanneer een persoon de motivatie en de mogelijkheid heeft om informatie te verwerken. Motivatie is daarmee een belangrijke contextuele variabele, en de mogelijkheid om informatie te verwerken is een belangrijk onderdeel van het mechanisme dat zorgt voor verandering in overtuigingen en evaluaties. Het conceptuele model van de effectiviteit van modelbouw, is dus gebaseerd op theorieën over overreding (context en mechanisme) en de theorie van gepland gedrag (resultaten).

De overgang naar het empirische deel van de studie wordt gemaakt in *hoofdstuk vijf*. Hier worden de theorieën uit het voorgaande hoofdstuk gebruikt om de onderzoekshypothesen te formuleren. In de hypothesen wordt de verwachte invloed van modelbouw op resultaten en mechanisme omschreven: de verwachting is dat group model building leidt tot een uitwisseling van informatie en een verandering in overtuigingen, evaluaties en acties. Daarnaast worden hypothesen geformuleerd over combinaties van context, mechanisme en uitkomst zoals die in hoofdstuk drie zijn geformuleerd.
Op basis van verschillende afwegingen over onderzoeksdesigns wordt uiteindelijk het pretest-posttest one group design gekozen. Een aantal bedreigingen voor de validiteit van een dergelijk onderzoeksdesign wordt beschreven. De operationalisatie en het ontwikkelen van schalen voor het meten van de centrale begrippen is gebaseerd op de theorieën uit het vorige hoofdstuk.

*Hoofdstuk zes* omschrijft in het kort de context, het proces van modelbouw en de uitkomsten van de vijf cases die in de studie onderzocht worden. De organisaties die in vijf cases centraal staan zijn verschillende partijen die betrokken zijn bij de veiligheid in een stadswijk (onder andere gemeente, bewoners, woningcorporaties, jeugd- en jongerenwerk), het Directoraat-Generaal Telecommunicatie en Post van het Ministerie van Verkeer en Waterstaat, de afdeling Research van een telecommunications provider en twee woningcorporaties. Voor iedere case wordt de organisatie, het probleem, de deelnemers en begeleiders, de methode van modelbouw, de verslaglegging en uitkomsten van het project voor de organisatie beschreven.

In *hoofdstuk zeven* staan de resultaten van het empirische deel van de studie centraal. De resultaten ten aanzien van de context, het mechanisme en de uitkomst worden apart beschreven. Ten aanzien van de context worden twee vragen behandeld: zijn de verwachte contextvariabelen terug te vinden in de vijf cases? Zijn de contextvariabelen aan elkaar gerelateerd? Het blijkt dat de deelnemers inderdaad een hoge motivatie hebben om informatie over de gemodelleerde problemen te verwerken. Motivatie hangt niet samen met de andere contextvariabelen (bijvoorbeeld leeftijd).
Dezelfde vragen worden beantwoord ten aanzien van het mechanisme. Ook de hypothesen over het mechanisme hoeven niet verworpen te worden: deelnemers oordelen positief over zowel de informatie die over het probleem uitgewisseld is, als de mogelijkheid tot verwerken van die informatie. Onderdelen van het mechanisme blijken weinig samenhang te vertonen.

Cognities, evaluaties en gedrag vertonen kleine veranderingen tussen voormeting en nameting. De onderlinge verbanden tussen de uitkomsten van modelbouw zijn zwak, wat in meer sociaal-psychologische studies het geval is.
Het hoofdstuk gaat vervolgens in op de relaties over verschillende categorieën, bijvoorbeeld: hoe beïnvloeden de contextvariabelen het mechanisme en de uitkomst? Dit beantwoordt de hypothesen over het effect van modelbouw op uitkomsten: leidt de informatie die wordt uitgewisseld in de modelbouwsessies tot een verandering van overtuigingen en evaluaties? Als de veronderstelde variabelen in de context en het mechanisme van modelbouw aanwezig blijken te zijn, verwachten we dat ook de hypothesen over de uitkomst niet verworpen hoeven te worden. Inderdaad blijkt één van de drie overtuigingen en twee van de drie evaluaties te veranderen onder invloed van uitgewisselde informatie. Gedrag verandert ook, onder de conditie dat gedragsopties en de aanbevelingen uit het modelbouwproject op hetzelfde niveau van abstractie zijn, en veranderingen ondersteund worden door bijvoorbeeld een actieplan. Tot slot wordt onderzocht of de vijf cases de verwachte combinaties van context-mechanisme-uitkomst laten zien. Er worden geen verschillen tussen de combinaties gevonden.

*Hoofdstuk acht* bevat de conclusies van deze studie en een discussie van de resultaten. Ten eerste wordt de waarde van het conceptuele model bezien, zoals dat in hoofdstuk vier afgeleid is uit de theorie van gepland gedrag en theorieën over overreding. De resultaten worden vergeleken met ander onderzoek op het gebied van modelbouw, gaming en gedrag in organisaties in bredere zin.
Ten tweede worden de voordelen en beperkingen van de meetmethode bekeken.
De resultaten van het empirische deel en de opmerkingen over het conceptuele model geven aanleiding tot een aantal verbeteringen aan de methode modelbouw. De uitkomst dat modelbouw inderdaad effect heeft op (sommige) evaluaties, maakt het mogelijk aanbevelingen te doen voor toekomstige modelbouwprojecten. De theorieën over overreding laten zien dat informatie over een minder belangrijk onderwerp maar heel summier wordt verwerkt. Aangezien de kracht van modelbouw ligt in het boven water krijgen en structureren van informatie, lijkt het belang dat deelnemers aan een probleem hechten daarom cruciaal: een deelnemer die het probleem niet belangrijk vindt, doet niets met de uitgewisselde informatie en doet geen nieuwe inzichten op. Daarnaast moet de aansluiting van informatie op de kennis die een deelnemer al heeft, bewaakt worden. Informatie waarvan de relevantie niet wordt ingezien heeft ook geen effect op ideeën of acties van een deelnemer. Modelbouw lijkt ook verbeterd te kunnen worden ten aanzien van het ondersteunen van gedragsverandering. Modelbouwers moeten meer bieden dan alleen informatie, en deelnemers duidelijk maken hoe ze aanbevelingen kunnen vertalen in veranderingen in hun organisatie. Tot slot kan modelbouw ook beter

aangepast op specifieke organisatie- en probleemcontexten. Wanneer modelbouw ingezet wordt in een politiek gevoelig probleem, zou het heel anders kunnen werken (via een ander mechanisme) dan in een andere situatie. Deze combinaties verdienen meer aandacht in toekomstige interventies.

Het hoofdstuk eindigt met aanbevelingen voor toekomstig onderzoek.

## Curriculum vitae

Etiënne Rouwette graduated in psychology and completed a master's thesis on psychonomy and gamma-informatics in 1994. From 1994 on he worked at the Methodology Department of Nijmegen School of Management at Nijmegen University. From 1996 to 2001 he worked as a PhD. student and since then as assistant professor. In addition to lecturing and research he works in applied projects using modelling, electronic meeting support and other methods.